7.0 FATE AND TRANSPORT OF CONTAMINANTS

7.1 HISTORICAL EVIDENCE

The Lehigh Valley Railroad derailment and spill at Gulf Road occurred at about 3:30 a.m., on Sunday, December 6, 1970. According to newspaper reports published later that week, "chemical" odors were detected in the basement of the Knickerbocker Hotel within three or four days of the derailment. The newspaper articles also indicated that the residents of some of the homes along Gulf Road had been temporarily evacuated, but that they were allowed to return to their homes on December 9th. Subsequent newspaper reports indicated that chemical odors and tastes were detected in water from wells at 8339 and 8389 Gulf Road. The articles also indicated that since that time, the residents had been obtaining household water from other sources. Such reports were corroborated by the former owner of the Knickerbocker hotel, and by Mr. George Marshall, a geological consultant to the Lehigh Valley Railroad after the derailment, in an interview and deposition in 1992.

A newspaper report in February 1971 indicated that two wells on Church Road, located approximately 3,300 feet southeast of the spill site, were apparently impacted by TCE from the derailment spill in late December 1970, or early January 1971. The report further indicates that the two wells were located at 8871 Church Road and 8875 Church Road.

On the basis of reported conditions at the time of the spill: i.e., the shallow (less than 10 feet) depth to bedrock, the eastward grade of Gulf Road, and the proximity of the wells to the spill site (less than 1,200 feet), it is not surprising that the domestic wells on Gulf Road were impacted shortly after the derailment/spill. It is apparent that TCE, a liquid solvent, was able to enter the bedrock fracture system almost immediately, due to the permeability of the overburden and the shallow depth to bedrock. Since the open hole rock wells likely had only short sections of well casing driven or set a few feet into the rock, the uncased, deeper portions of the wells were susceptible to infiltration of the liquid TCE (NAPL) along any rock fractures intercepted by the well bore. In addition, Mr. Marshall reported the presence of an "emulsion" of TCE and groundwater in the Tyler well shortly after the spill.

As stated above, it would be reasonable to expect an impact on the wells on Gulf Road east of the spill site within a very short period of time. Similarly, it would be reasonable to expect that much of the TCE would enter the rock fractures intersected by the valley of Mud Creek and would be carried away to the northeast through this valley, an obvious surface and groundwater pathway. The transport of TCE out of this valley would have been enhanced if surface water was flowing in the creek at the time of the spill. Mr. Marshall has testified (Marshall, 1992) that TCE odors could be detected in the face of the Mud Creek falls in the spring of 1971. This indicates that some of the TCE and/or TCE-contaminated surface and/or groundwater was migrating into this drainageway in early 1971. However, based upon the water level monitoring results from the current investigation, it is probable that groundwater levels were depressed at the time of the spill and that Mud Creek was not flowing. If this was the case, the TCE could have moved deeper into the ground almost immediately and traveled both horizontally and vertically along bedrock fractures (bedding planes and joints) in multiple directions. Some of the TCE would have eventually reached the water table where it would have been dispersed with, and/or dissolved in, the groundwater flowing beneath the area.

The reported impact on the wells on Church Road, within approximately one month of the spill, is more significant with respect to the migration of the NAPL away from the spill site. The impact on these wells highlights the fact that some of the TCE-contaminated groundwater passed beneath the valley of Mud Creek and migrated at least 3,300 feet to the southeast in a month. The transport mechanism was obviously groundwater flow along the available migration route(s), i.e. the bedrock fractures.

7.2 EXTENT OF CONTAMINATION

7.2.1 West of Church Road, Including Spill Site

Overburden

The results of DUNN's spill site soil investigation (see Spill Site Soil Investigation Report in this volume of the RI report) indicated that approximately 15,000 cubic yards of overburden (fill/soil) materials are contaminated with TCE in excess of the NYSDEC recommended soil cleanup objectives. Concentrations of TCE remaining in the spill site overburden are still as high as 570 ppm. The contaminated overburden is located in the immediate vicinity of the derailment/spill site, both north and south of Gulf Road. Infiltrating precipitation continues to leach TCE from the overburden and transports it downward until it reaches the water table. These soils, therefore, are acting as a continuing source of groundwater contamination. The approximate area of contaminated soils is shown on Figure 5 of the spill site soil report.

Bedrock Vadose (Unsaturated) Zone

The results of the various phases of the RI indicate that TCE continues to be present in bedrock above the water table (vadose zone), primarily in the vicinity of the derailment/spill location. The evidence includes the results of HNU scans of bedrock core and rock chips, the results of field GC analyses of rock chips, and analysis of groundwater samples collected during a period of seasonal high water levels (April 1994).

Analysis of rock chips at boring DC-16 detected contamination in the mid to upper Clarence member of the Onondaga Formation, 15 to 25 feet below the ground surface. Somewhat higher levels of TCE contamination were detected in rock chips from boring DC-17B, in the Bois Blanc to upper Falkirk interval, 40 to 50 feet below ground surface. HNU scans of freshly retrieved core at boring DC-1D (at the spill site) detected total VOCs as high as 70 ppm in fractures in the mid to upper Clarence, 18 to 32 feet below ground surface. HNU scans of rock chips from the mid Clarence to upper Falkirk at DC-1B were in the 20 ppm range, 30 to 60 feet below ground surface.

Analysis of groundwater samples collected from open-hole monitoring wells located west of Mud Creek indicates that TCE concentrations can be positively correlated with groundwater levels. Refer to Table 7-1 for evidence of this relationship. This suggests that pure TCE, i.e., NAPL, is present in bedrock that is typically above the water table, except during periods of high water levels in the spring of the year. Although testing for the presence of NAPL above and below the water table was conducted during the drilling program, NAPL was not detected in any of the samples.

Groundwater

The field GC analysis of groundwater samples from packer-isolated zones provides a good indication of the vertical extent of contamination at the time the borings were advanced (see Table 2-3). TCE concentrations decreased sharply at depths of approximately 80 to 100 feet in borings DC-1, DC-2, DC-3, and DC-5. TCE levels also decreased in borings DC-6 and DC-7R, where the comparable depths are 65 feet and 140 feet, respectively. These results suggest that, at the time of drilling, contaminated groundwater may have been present primarily in the mid Clarence to upper Camillus interval. Results of NAPL testing on these same groundwater samples were always negative. As previously discussed in Section 6.4.3, local water quality may have been temporarily degraded at four drilling locations during the drilling/well installation program (DC-1, DC-2, DC-5, DC-15). Four rounds of analytical data indicate that the contamination is deeper at these locations than is suggested by the field screening results (see Table 2-3). The analytical data further indicate that the TCE concentrations are declining in the potentially impacted deeper wells at locations DC-1, DC-5 and DC-15. Analytical results from samples collected at domestic wells during the monitoring program provide no evidence of increased levels of contamination related to the concentrations in the monitoring wells shortly after their installation.

Despite the negative test results for the presence of NAPL, it is likely that pure TCE is present in the vicinity of a few monitoring wells. Groundwater analytical data showing TCE concentrations in excess of 1% of solubility, or 11,000 μg/l, are widely accepted as providing indirect evidence of the presence of NAPL. Concentrations exceeding 11,000 μg/l have been detected at least once at locations DC-1, DC-5, and DC-15, suggesting the presence of NAPL in either unsaturated or saturated bedrock, or both. It is considered likely that a larger proportion of the original volume of pure TCE remains in the vadose zone, in comparison to the volume of TCE in the saturated zone at these locations. The vadose zone TCE contacts groundwater for only several weeks per year when water levels are high, whereas the saturated zone TCE has been dissolving in groundwater for 24 years. Both of these sources of TCE have created and sustained the dissolved phase plume that now extends for a distance of nearly four miles in an easterly direction from the spill site. The area underlain by possible NAPL, as shown on Figure 7-1, covers approximately 10 acres. The analytical results suggest that NAPL may extend to depths of 65 feet, the maximum depth of the three impacted open-hole wells (DC-1A, DC-5A, and DC-15A).

The concentrated dissolved phase plume, defined as groundwater with TCE concentrations <u>generally</u> exceeding 1,000 μg/l, is shown schematically on Figure 7-1. The plume outline is generalized in that many of the included wells (monitoring as well as domestic) may have tested below 1,000 μg/l one or more times. The area underlain by the generalized 1,000 μg/l plume is approximately 66 acres. Assuming an effective porosity of 5%, a plume "thickness" of 75 feet, and a mean TCE concentration of 2,000 μg/l, the volume of TCE in the plume is approximately 111 gallons.

The southwest lobe of the plume indicates that contaminated groundwater is drawn toward the water supply well at the Dolomite Products Company quarry. There are two pumps in the well (G5). The shallow pump (G5S), set at an unknown depth, provides water that is treated and used for human consumption. The deep pump (G5D), reportedly set in the upper Camillus at a depth of 140 feet, provides water for stone washing operations at a rate of 280,000 gpd. Neither pump operates during the winter months (Matt McCormick, personal communication). Contamination detected in the quarry discharge water indicates that TCE contaminated groundwater flows, or is drawn, toward the southwest in the (quarried) lower members of the Onondaga Formation.

The water has not been sampled directly from the sump, but rather from the end of a discharge pipe located approximately 500 feet from the quarry (SW-17).

7.2.2 Mud Creek Gorge

With the exception of SPR-4, the five springs in the Mud Creek gorge north of Gulf Road are seasonal features. SPR-3 yielded its highest TCE result in April 1994 (during high water levels), whereas the remaining springs exhibited their lowest concentrations at that time. The springs are discussed below, in order of increasing distance from the spill site. The springs become deeper in the stratigraphic section as the distance from the spill site increases. With the exception of SPR-3, the range of TCE concentrations decreases with increasing stratigraphic depth and distance from the spill site. Surface water analytical results from the gorge pond extend this trend farther to the northeast.

SPR-3 is located in the upper strata of the dolomitic Bertie Formation. This spring has been sampled three times, and has shown TCE concentrations that range between ND and 270 μg/l. Locations SPR-20 and SPR-20A are projected (from well cluster DC-6) to be at the contact between the Falkirk member of the Bertie, and the Camillus Formation. These springs, with TCE concentrations ranging from 95 to 630 μg/l, are the most contaminated springs identified in the Mud Creek area. Spring No. 7 is frequently dry, and has been sampled only twice. TCE concentrations were 39 and 130 μg/l. This spring is projected to be in the Camillus, approximately 29 feet below the top of the formation. SPR-4, formerly used as a water supply by a local residence, is located a few tens of feet from the gorge pond. This spring is projected to be in the Camillus, approximately 35 feet below the top of the formation. The spring has been sampled six times with very consistent TCE concentrations, ranging from 40 to 98 μg/l.

Surface water in the gorge pond has been sampled in two locations, one near the upstream end (29 μg/l), and one at the dam (6 μg/l).

7.2.3 Church Road to Spring Creek

Available data suggest that the downgradient plume (i.e., Church Road and eastward) is rather constricted in the vicinity of Church Road, and broadens considerably to the east (Figure 7-1). Evidence for the constriction includes analytical data from domestic wells in the area (G7 through G12), and from monitoring well DC-7 and well cluster DC-7R. Comparison of TCE concentrations with water levels in DC-7RA (Table 7-1) indicates that groundwater in the Onondaga Formation appears to be clean, and that contamination is present in the Bois Blanc, Scajaquada, and uppermost Falkirk. Contaminant concentrations at cluster DC-7R indicate that the plume is between 75 and 100 feet thick in this area, and that it extends downward at least into the middle Camillus Formation.

As previously discussed, well DC-7 has been below the MCL, and DC-7RA has been contaminated on the two occasions when both wells were sampled. The wells are 410 feet apart, along the west side of Church Road. Well G-9, on the east side of Church Road, is located just north of well cluster DC-7R. This well is typically contaminated at levels two to three times greater than those in DC-7RA and DC-7RB, which together monitor equivalent strata as G-9. The next domestic well to the north (G-8) has been ND for TCE for the past three years. The next domestic well to the south of G-9 (G-10) has contained TCE at levels comparable to those in monitoring wells DC-7RA and DC-7RB. Contamination drops sharply, to just above the MCL, at the next domestic well to the south, G-11. Wells farther to the south along Church Road are ND for TCE. These data suggest that the north-south extent of the plume at Church Road is less than 750 feet, the approximate distance between domestic well G-11 and monitoring well DC-7.

The density of both domestic wells and monitoring wells is much lower in the central part of the Study Area. The available evidence indicates that the plume becomes considerably broader to the east of Church Road, up to perhaps one mile in the north-south direction. TCE concentrations also drop markedly from the ppm levels at domestic well G-9 to the (generally) 50 μg/l range or less at well clusters DC-8, DC-9, DC-10, DC-11, and DC-12, and at the contaminated domestic wells near three of these clusters (DC-8, DC-9 and DC-12). Domestic wells near DC-10 (L-1 and L-14) have generally contained TCE in the range of 100 to 200 μg/l. There are no domestic wells in the immediate vicinity of DC-11. The apparent north edge of the plume traces a fine line in Monroe County between domestic wells G-6 and M-2, M-6 and M-7, M-12 and M-13, and M-27 and M-35. Refer to Figure 3-1 for the locations of the domestic wells. The consistent absence of contamination in domestic well M-1 is interesting, considering its location with respect to the spill site, and to contaminated domestic wells to the east, northeast, and southeast. Domestic well and monitoring well analytical data (DC-8, DC-9, and DC-10) indicate that contaminated groundwater flows through the Falkirk member and the upper Camillus Formation. The vertical extent of the plume varies seasonally, particularly at DC-8 and DC-9, and, at its maximum thickness, is no more than 70 feet thick.

Like the north edge of the downgradient plume, the south edge also traces a fine line, in this case between domestic wells G-11 and G-12, and L-4 and L-2. Monitoring well pair DC-11 appears to be just outside of the south edge of the plume. However, for areas east of Callan Road, the location of the south edge of the plume is presently unknown. Domestic wells sampled along Graney Road have been ND for TCE, but these wells are not deep enough to intersect the strata likely to be contaminated. If the reported depth of domestic well L-2 is correct (90 feet), then the analytical data from that well and from well cluster DC-12 suggest that contaminated water flows through strata from the top of the Bertie to the upper Camillus. The apparent vertical thickness of the plume is approximately 65 feet in this area.

Considering the distance from the spill site, the terminus or easterly limit of the plume along Spring Street is characterized by relatively high levels of contamination. TCE concentrations in the 25 to 100 μg/l range are typical in domestic wells located within approximately 1,000 feet (on either side) of the Monroe-Livingston County line. SPR-12 has consistently yielded TCE results (46-100 μg/l) comparable to those from nearby Livingston County domestic wells. This spring is projected to be in the Falkirk. Well pair DC-13 is located just to the north of the group of contaminated domestic wells in Monroe County. TCE concentrations at DC-13 (10-26 μg/l) compare favorably with those at the nearest domestic well (M-35). Contamination is present in the middle Camillus to upper Syracuse strata in DC-13, and is projected to be in the same strata in the domestic wells. This represents the greatest stratigraphic penetration of TCE contamination in the Study Area. The maximum depth of contamination is unknown at the easterly end of the plume, since the deeper well at each monitoring well pair is consistently contaminated.

Concentrations are much lower in the domestic wells and in the voluminous springs along the southern half of Spring Street. The domestic wells have exhibited low levels (< 2 μg/l) of TCE (L-25, L-30 and L-39), and the springs (SPR-11, SPR-18 and SPR-26) have been generally free of TCE contamination. The only deviation from this pattern is SPR-21 (1,900 μg/l), which was sampled in the spring (April 1994) of the year. SPR-26, which is located approximately 100 to 150 feet to the northwest of SPR-21, was clean at this time. Both springs were dry for the remainder of the year and could not be resampled. Analytical results at well pair DC-14 (6-14 μg/l of TCE) are comparable to those at nearby domestic well L-31. Contamination is present in the Falkirk and upper Camillus at DC-14, whereas to the south of that well, slightly contaminated springs that supply Spring Creek occur in the overlying members of the Bertie.

The general area underlain by the groundwater plume with TCE concentrations in the range of 100-1,000 μg/l is approximately 726 acres or 1.1 square miles. Assuming an effective porosity of 5%, a plume "thickness" of 70 feet, and a mean TCE concentration of 150 μg/l, the volume of TCE in this part of the plume is approximately 85 gallons.

The general area underlain by the groundwater plume with TCE concentrations in the range of 5-100 μg/l is approximately 1,128 acres or 1.8 square miles. Assuming the same effective porosity and plume "thickness", and a mean TCE concentration of 50 μg/l, the volume of TCE in this part of the plume is approximately 6 gallons.

The estimated TCE volume in the entire three square mile dissolved phase plume (TCE >5 μg/l) is, therefore, approximately 200 gallons, or less than 1% of the volume of TCE reportedly spilled (30,000 gallons) in the train derailment.

7.3 ENVIRONMENTAL FATE OF TCE AND CYANIDE

The principal contaminants of concern associated with the derailment/spill are TCE and, to a significantly lesser extent, its potential degradation products and cyanide. The data indicate that very little degradation of TCE has occurred and; therefore, the environmental fate of the potential TCE breakdown products is not discussed.

The physical and chemical properties of TCE and its reaction in the environment are presented below and discussed in the following text.

Molecular Weight	131.4
Boiling Point	86.7°C
Density	1.464 g/cc
Solubility at 25°C	1,100 mg/l
Koc (Partition Coefficient)	126 g/ml
Log Kow	2.53
Henry's Law Const. at 20° C	0.0117 atm * m /mol
Bioconcentration Factor	17 to 39

The high solubility and low partition coefficient values (Kow and Koc) for TCE indicate that it will be highly mobile in soil and will exhibit a tendency to leach to groundwater. The low Koc indicates that adsorption to sediments will generally not be significant. However, in sediments with high organic carbon concentrations, TCE can adsorb to sediments. The high density indicates that pure TCE can exist and behave as a dense non-aqueous phase liquid (DNAPL) in the subsurface environment. The low bioconcentration factor indicates that TCE does not bioaccumulate.

The Henry's Law Constant indicates that TCE will readily volatilize from surface water to the atmosphere. The primary aquatic removal process will be evaporation, with the half life dependent on the surface water turbulence. This tendency, along with dilution, most likely accounts for the low concentrations of TCE detected in surface water samples from Mud and Spring Creeks, even though spring samples in the vicinity have exhibited elevated TCE concentrations.

Abiotic (hydrolysis and oxidation) and biotic (microbial) degradation of TCE has been documented in the literature. The abiotic degradation process is relatively slow, with a reported half life of 0.9 years. Research has indicated that biotic degradation products of TCE include 1,2-dichloroethene (primarily the cis isomer) and vinyl chloride. However, in order for biotic degradation to occur, field conditions must be conducive to bacterial life, and bacterial populations capable of degrading chlorinated compounds (such as methanogens and sulfate reducing bacteria) must be present at a site. Groundwater analytical data from the Study Area indicate that neither abiotic nor biotic degradation of TCE is occurring to any significant degree. Cis-1,2-dichloroethene has only been detected in a limited number of groundwater and surface water samples, and vinyl chloride has not been detected in any of the groundwater or surface water samples.

The cyanide reportedly spilled during the derailment was in crystalline form. This compound would tend to react with water and metals to form various forms of cyanide. The primary cyanide compound that would be formed in waters is hydrogen cyanide. The physical properties of hydrogen cyanide are summarized below:

Molecular Weight	27.03
Boiling Point	25.70°C
Density	0.6684 g/cc

Solubility	Miscible with water
Log Kow	0.66
Vapor Pressure	264.3 mm Hg

In soil, crystalline cyanide would tend to react with soil moisture to form hydrogen cyanide and, potentially, soluble alkali metal salts or insoluble metallocyanides. The fate of cyanide in soil would be pH dependent. At soil surfaces with pH < 9.2, hydrogen cyanide would be highly mobile and could leach downward to the watertable. Also, in surface soils with pH <9.2, volatilization of hydrogen cyanide would be an important loss mechanism for the cyanide.

In water, the crystalline cyanide would most likely form hydrogen cyanide, which is the most common form of cyanide in water. However, it can also occur as an alkali metal or various metallocyanide complexes of varying stability. The alkali metals salts are very soluble in water and will dissociate to the metal cation and the cyanide anion. The cyanide anion will then tend to form hydrogen cyanide. When the cyanide ion is present in an excess, complex metalocyanides may form. Some metalocyanides are readily soluble and may ultimately dissociate and form hydrogen cyanide. Insoluble metalocyanides may potentially absorb to sediment and bioaccumulate in aquatic organisms. With the exception of one sediment sample (SED-2, July 1994), the sediment sample cyanide results were non-detect for total cyanide, indicating that complex metal cyanides are not being formed.

At a pH < 9.2, most of the free cyanide should exist as hydrogen cyanide, which is highly volatile. The rate of volatilization will be dependent on temperature, pH, water turbulence and cyanide concentration. Biodegradation may also play an important role in the fate of hydrogen cyanide in natural water systems. A number of microrganisms have been shown to degrade low concentrations of cyanide under both aerobic and anaerobic conditions. Hydrogen cyanide has a low log Kow (0.66) and is, therefore, not expected to adsorb significantly to suspended solids, sediments or soils, or to bioaccumulate significantly in aquatic organisms.

7.4 TRANSPORT OF CONTAMINANTS

The following brief discussion of NAPL behavior in the subsurface is taken largely from Mercer and Cohen (1990). Subsurface NAPL migration is affected by: 1. the volume of NAPL released; 2. area of infiltration; 3. duration of the release; 4. properties of the NAPL; 5. properties of the media; and 6. hydrogeological conditions. When introduced into the subsurface, gravity causes the NAPL to migrate downward through the vadose zone as a distinct liquid. This downward migration is also accompanied by some amount of lateral spreading. Residual liquid remains trapped in the pore spaces as the NAPL front continues its descent. This residual saturation results from surface tension effects. Some of the NAPL may volatilize, creating a vapor "halo" which extends beyond the NAPL.

If the NAPL is denser than water (DNAPL), it will displace water upon reaching the saturated zone, and continue migrating under the influence of pressure and gravity forces. Low-viscosity DNAPL, such as TCE, is extremely mobile, and will flow downward even in the presence of upward hydraulic gradients. Preferential spreading will occur where DNAPL encounters relatively permeable layers, such as fractures. If the volume of DNAPL is sufficient, the liquid will descend until a barrier layer is encountered, upon which it may continue to flow under pressure and gravity forces. As in the vadose zone, some of the NAPL will be immobilized in pore spaces in the saturated zone. Until it is completely dissolved - a process that may occur over a period of decades - residual NAPL will act as a continuing chemical source to the flowing groundwater.

7.4.1 Infiltration Through Contaminated Overburden

Because of its relatively low affinity for adsorption to soils, TCE is leached (by infiltrating water) from the contaminated overburden/fill in the vicinity of the spill site, and transported downward into the bedrock. TCE vapors may also be dissolved and carried downward by the infiltrating water. This transport occurs during and following precipitation and snowmelt events. Some of the contaminated infiltrating water may provide recharge to the hydrogeologic system, while some remains in the vadose zone. Whether recharge actually occurs is dependent on the volume of infiltrating water, the duration of the precipitation or melting event, the infiltration capacity of the soil/overburden, and the storativity and moisture content of fractures in the vadose zone. The groundwater that remains in the vadose zone may become further contaminated as a result of prolonged contact with residual or pooled NAPL that may be trapped in fractures.

7.4.2 Dissolution of NAPL

The water table elevation (level) at the spill site fluctuated by approximately 30 feet during the 10-month monitoring period. During the spring months, the rising water entered fractures that are usually dry. For an indication of the vadose zone strata, refer to Figure S-1 in Appendix S, which shows the strata, screen positions, and water level ranges for well cluster DC-1, which is located at the spill site. The analytical results for the April 1994 sampling event suggest that some amount of non-aqueous phase TCE is present in these relatively shallow fractures, near wells DC-1A, DC-5A, and DC-15A. The approximate area that may be underlain by NAPL-bearing strata is shown on Figure 7-1. TCE concentrations in groundwater samples from these three wells exceeded 1% of TCE solubility, widely regarded as an indication of the local presence of NAPL. The April concentrations were the <u>highest</u> levels detected during four sampling events at these three wells. Water levels in April were also the highest during any sampling event (Table 7-1).

The highest TCE concentrations also occurred in April in two additional open-hole wells west of Mud Creek (DC-6A and DC-16), although the levels were not indicative of NAPL. The high concentrations in all five of these wells suggest that rising groundwater came into contact with NAPL present in the relatively shallow fractures, and generated a highly contaminated "slug" of groundwater. In contrast, TCE concentrations in April were at their <u>lowest</u> levels in three open-hole wells located in the area between Mud Creek and Church Road. This suggests that the high-concentration TCE plume near the spill site moved in a direction other than east or southeast. The potentiometric surface map (Figure 5-26) provides an indication of where the plume may have gone.

Figure 5-26 shows that, during periods of high water levels, groundwater moves from the spill site in a northeasterly direction toward the Mud Creek gorge. Although the nearby wells east of Mud

Creek are cross-gradient or downgradient of the spill site, they may be subject to an influx of clean groundwater from the recharge zone beneath the south pond along Mud Creek. This could account for the relatively low concentrations of TCE during high water levels in this area, particularly at monitoring wells DC-7RA and DC-17A, and at the Dolomite Products well (G-5S and G-5D). Figure 5-25 indicates that, as groundwater levels recede, groundwater flow returns to the more normal east-southeasterly direction. The resumption of this flow direction may account for the abnormally high TCE concentration (8,600 μg/l) detected in July 1994 at well DC-3A, and for the return to earlier, higher TCE levels at wells DC-7RA and DC-17A.

NAPL may also occur below the water table at wells DC-1A and DC-15A. These wells yielded groundwater samples with TCE concentrations above 1% of TCE solubility in November 1993, when water levels were well below seasonal highs (Table 7-1). In contrast, DC-5A had TCE concentrations below the 1% level during the November sampling event. This suggests that NAPL may be restricted to somewhat shallower, normally unsaturated, depths at this location, approximately 600 feet south (down structural dip) of the spill site.

Given the volume of the spill, it is not surprising that NAPL may have penetrated bedrock to depths below the water table. The volume of NAPL present <u>below</u> the water table at the present time is expected to be lower than the volume present <u>above</u> the water table. (If the opposite were true, TCE concentrations would not increase with rising groundwater levels.) Initially, NAPL volumes below the water table were probably lower because there are more fractures for the NAPL to enter in the shallower subsurface than in the deeper subsurface. Subsequent to the spill, NAPL in saturated rock has been dissolving in groundwater for 24 years. NAPL in the vadose zone is in much less frequent contact with water, and may be present at volumes closer to those originally present shortly after the spill.

Because NAPL has not been directly detected at the Site, the specific modes of occurrence of non-aqueous phase TCE (as small pools, tendrils, globules, etc.) are not known. Residual NAPL, by definition, is immobile. Although unlikely, it is possible that any pooled NAPL present above the water table may be mobilized by rising groundwater and may migrate away from the spill site, or deeper into the bedrock. It is likely, however, that NAPL migration has ceased by this time, 24 years after the spill. This implies that NAPL may not flow toward or into wells under natural gradients. Whether above or below the water table, the slowly dissolving NAPL acts as a continuing source of groundwater contamination, and is responsible for the presence of the extensive, dissolved-phase TCE plume in the Study Area.

7.4.3 Controls on the Dissolved Phase Plume

Geological features and the locations of groundwater recharge and discharge areas control the shape of the plume. Figure 5-1 shows, in a general way, the boundary of the TCE plume, and some of the relevant geomorphological and hydrogeological features of the area. Seasonal discharge to the Mud Creek gorge, and pumping of the Dolomite Products Company well results in a northeast-southwest elongation of the west end of the plume (Figure 7-1). The general east-west orientation of the downgradient plume is strongly influenced by regional discharge to Spring Creek, and possibly to the deltaic deposits to the south and east of the Village of Caledonia.

Recharge from infiltrating precipitation in areas north of Flint Hill Road (Monroe County) likely flows in a southerly (downdip) direction. Runoff from the till-covered uplands south of Route 5 flows in a general northerly and then easterly direction as it reaches the exposed limestone bedrock surface. This runoff provides groundwater recharge along an east-west-oriented belt located at the southern limit of the exposed bedrock. Well cluster DC-12 is the only cluster within the entire Study Area that exhibits a downward gradient for the entire year. The resulting groundwater mound may create a pressure gradient that limits the southward migration of the contaminant plume. The plume may be hydrodynamically confined between these two recharge areas. The presence of the southern recharge belt may explain the absence of contamination in domestic wells along Route 5 between Church and Callan Roads. The recharge belt is interpreted to be displaced toward the south, east of Callan Road, matching the more southerly position of exposed bedrock in this area. This displacement may allow the plume to move farther to the south, accounting for the contaminated domestic wells along Route 5, east of Callan Road.

While the distribution of contamination in well cluster DC-12 appears to define the depth of the plume in this area, the southern extent of the plume is not presently known to the east of this cluster. Groundwater in this area may flow east-southeasterly, bypassing Spring Creek, and "discharge" into the deltaic deposits south of the Village of Caledonia. These deposits are located within the Genesee River watershed.

A competent, relatively impermeable layer of rock that defines the lower limit of the plume does not appear to be present in the Study Area. The apparent "plume bottom" in the upper Camillus may be controlled hydrodynamically by the upward hydraulic gradient that generally prevails year-round in the lower Camillus. Alternatively, or perhaps additionally, the lower Camillus may be clean because of the large volume of water that moves through the highly permeable, broken rock that constitutes the lower part of the unit. The lower Camillus and Syracuse are consistently contaminated at concentrations above the MCL only at DC-13, where the hydraulic gradient is downward, and the Falkirk and upper Camillus have been eroded away. The maximum depth of contamination is unknown at the east end of the plume. It is possible that contaminated groundwater flows beneath Spring Creek, and "discharges" into the thick, extensive deltaic deposits that underlie the Village of Caledonia. NYSDOH has sampled several domestic wells that penetrate these deposits on the east side of the creek. These wells have all tested below the MCL for TCE. If contaminated groundwater enters these deposits, it is probably rapidly diluted by clean groundwater in this presumably high-porosity medium.

Lateral and vertical migration of the plume occurs through bedding plane and high-angle fractures. These fracture systems have been identified at all stratigraphic levels within the Study Area. The caliper logs (Appendix I) show that bedding plane fractures often occur at the same stratigraphic position in different borings. This suggests, but does not prove, that the fractures are continuous in the strata between such borings. Fracture density varies widely, however, from boring to boring. In boring DC-1A, for example, the Edgecliff, Bois Blanc, and Scajaquada are relatively unfractured.

The presence of contamination in the underlying Falkirk (DC-1B), however, indicates that transport nevertheless occurs across the 11-foot-thick interval (fractures could be present just beyond the borehole in this same interval.) In contrast, the same stratigraphic interval (Edgecliff - Scajaquada) is much more fractured at location DC-4, located 900 feet from (northwest of) the spill site. Strata penetrated by boring DC-6 appear to be the most heavily fractured strata, in general, in the area west of Church Road. To the east of Church Road, intense fracturing has been noted from the ground surface to the total depth (160 feet) of boring DC-11. The video log (Appendix I) shows this clearly.

Groundwater transport is rapid through solution-widened fractures, and relatively slow through narrow-aperture fractures, such as those typically found in the Falkirk. The detection of contaminated groundwater in well G-9 on Church Road within one month of the derailment/spill demonstrates how rapidly water can move through fractured bedrock. The rock core and the geophysical and video logs at borings DC-1, DC-3, DC-7 and DC-7R demonstrate the presence of both horizontal fractures (bedding planes) and high-angle fractures (joints) in the rock at these locations. In fact, some of the bedding plane fractures appear to be correlative, and may be continuous between some of these boring locations. In particular, the geophysical logs indicate the apparent presence of bedding planes common to the Falkirk at locations DC-3 and DC-7R. A comparison of the caliper logs indicates that fractures are better developed at DC-7R than at DC-7, particularly in the primary geologic unit that appears to be transmitting the contaminated water, i.e. the Falkirk member of the Bertie Formation. This evidence could imply that the bedding planes are the primary conduits for the migration of contaminated groundwater. That is, the contaminated groundwater can migrate to well DC-7R along bedding plane fractures, whereas, since such fractures are less developed at location DC-7, the well remains uncontaminated.

It cannot be determined from the physical or chemical evidence gathered to date if one or the other of the fracture systems (i.e., bedding planes or joints) is carrying all, or most, of the contaminated groundwater in a southeasterly direction. The common occurrence of a contaminated domestic well "next door" to a well that provides potable water suggests that in certain areas, high-angle fractures, rather than bedding plane fractures, are the primary routes of groundwater flow. Figure 3-1 shows the distribution of contaminated domestic wells and their proximity to potable wells. The 5 μg/l contour on Figure 7-1 reflects this distribution.

Groundwater flows (with or without dissolved contaminants) in the presence of a hydraulic gradient. Lateral gradients drive the plume in a horizontal direction. Vertical gradients control the ascent or descent of the plume. In the Study Area, overall gradients are a combination of both lateral and vertical components, with the vertical component dominating. The common vertical gradients at most well clusters are 1) downward from the Onondaga and Bois Blanc Formations into either the Falkirk member of the Bertie Formation or the upper Camillus Formation, and 2) upward from the lower Camillus or Syracuse Formations into either the Falkirk member or the upper Camillus Formation. At well clusters located to the west of Church Road, the magnitudes of the vertical gradients generally exceed those of the horizontal gradients by several times. The net effect is that groundwater gradually descends into the Falkirk and upper Camillus as it flows in a general southeasterly direction. The upward head in the lower Camillus inhibits further downward flow. There are seasonal variations and local exceptions to this trend.

At well clusters located to the east of Church Road, the vertical gradients also exceed the lateral gradients, but by much smaller amounts. Groundwater flow is primarily horizontal in this area, and the descent of the plume is minimal. The analytical data generally support this interpretation of plume behavior.

The degree to which the Falkirk and upper Camillus are saturated controls TCE concentrations in monitoring wells DC-8B and DC-8C (Table 7-1), and in nearby domestic wells. When the water level in DC-8C was in the upper Camillus, nine feet below the top of the screen, the TCE concentration barely exceeded the MCL. The concentration rose to 58 µg/l when the water level rose 40 feet above the screened interval. This water level increase also saturated the Falkirk, which was sampled for the first and only time in April 1994. The TCE concentration in that sample was 88µg/l. This well is at the apparent northern edge of the plume. TCE concentrations in nearby domestic wells (M-2 and M-3) have also shown a mildly seasonal trend.

A similar effect has been noted at well DC-9B, which screens the Falkirk and upper Camillus, and at nearby domestic wells M-13 and M-14. When the water level in DC-9B was in the upper Camillus, seven feet below the base of the Falkirk, the TCE concentration was below the MCL. When the water level rose to a point five or more feet above the base of the Falkirk, the TCE concentration rose to 16 to 20 µg/l. The 1993 and 1994 analytical results from domestic wells M-13 and M-14 also show a correlation between assumed water levels and TCE concentrations.

The previous detailed discussion of controls on the contaminant plume demonstrates the complexity of the contaminant migration pathways and the fact that either or both horizontal and high angle fractures in the bedrock can provide the transport routes for the TCE contamination east of the spill site. It would be difficult to predict with confidence whether a newly installed well at a particular location within the plume would be clean or contaminated. Water quality would have to be monitored for TCE, at least initially, in new or deepened wells.

7.5 VOLUME EXCHANGE TIME

An analysis was performed to calculate the approximate time it would to take to naturally replace the volume of water within the area that has been impacted by the contaminant plume. This impacted zone (IZ) encompasses the area from the spill site east to Spring Creek (a distance of approximately 20,000 feet), 10,000 feet south from Oatka Creek, and a thickness of 105 feet, the average saturated thickness of strata to the base of the Camillus Formation (Figure 7-2).

To calculate the volume exchange time (VET), a Hydrologic Basin approach was utilized to account for the indeterminable variables and the complex nature of the Study Area. By combining variables and evaluating their composite effect on the hydrogeological system within the Study Area, the system was reduced by those determined effects. A simple conceptual model was then developed to estimate the volume exchange time within the IZ. A conventional Darcy type groundwater flow equation was also applied to independently estimate a VET.

7.5.1 The Hydrologic Basin Approach

The Hydrologic Basin ("basin") approach involved four steps to estimate the time it would take to naturally replace water contained in the IZ. The first step was to determine the contribution to flow in Oatka Creek, at Garbutt, New York, as a function of basin area (Figure 7-2). The basin was defined as the area that contributes surface water or groundwater to the stream. The past three year, average seven-day minimum discharge and area for Oatka Creek recorded at Garbutt Station is 23 cubic feet per second (cfs), and 208 square miles, respectively (U.S.G.S., 1990). Based on this minimum discharge, a total basin wide contribution of 0.111 cfs/per square mile was determined (i.e. 23 cfs/208 sq.mi.).

Step two was to calculate the contribution to Oatka Creek from most of the combined Mud Creek and Spring Creek basins (MSB) by multiplying the discharge per unit area, as determined in step one, by the area of the Mud Creek watershed. This step was necessary because groundwater in the MSB is primarily responsible for flushing water through the IZ. This calculation yields 3.65 cfs. (i.e. 32.9 sq.mi. x 0.111 cfs/sq.mi.). Therefore, the MSB contributes 3.65 cfs to the flow of Oatka Creek as gaged at Garbutt, New York. The balance of the flow is contributed by drainage areas outside of the MSB.

The third step was to calculate the volume of the IZ. The volume is the product of the length (20,000 feet), width (10,000 feet) and thickness (105 feet) of the IZ, which equals 2.1×10^{10}cu.ft.

The fourth step was to calculate the time required to replace all the water within the IZ. The VET was calculated by multiplying the total volume of the IZ (2.1×10^{10}cu.ft.) by the effective porosity of the rock (assumed to be 10%), and dividing by the flow (3.65 cfs.). Based on this method, it would take approximately 18.2 years to flush a volume of water from the IZ.

<u>Assumptions and Rationale</u>

The use of the basin approach requires several assumptions about the water and hydrogeology of the basin. The effects of each assumption on the VET calculations were evaluated.

Assumption: The three-year average minimum discharge of Oatka Creek as measured at Garbutt Station does not reflect any significant surface water runoff and is a reasonable estimate of the steady rate at which groundwater is released from the water bearing zone.

Rationale: The flow rate measured at the gaging station consists of base flow readings and occasional storm surges. In low flow conditions, 100% of the flow is groundwater released from storage. The minimum flow rate is therefore a very conservative estimate of the steady rate at which water is released from storage. The VET is inversely proportional to the flow rate.

Assumption: Water is uniformly contributed to Oatka Creek by all areas of the basin.

Rationale: The relationship of the flow observed at Garbutt station to flow per unit area of the basin assumes that all areas of the basin contribute uniformly to that flow. This is certainly not true on a small scale since such factors as vegetation, slope, soil type, overburden thickness, fracture density, and stratigraphy will play an important role in determining runoff, infiltration rates, and evapotranspiration, locally. In the basin approach, however, these factors will tend to be normally distributed and will, therefore, average out. A change in the contribution attributable to the IZ would cause a directly proportional change in the VET.

Assumption: All water contributed to Oatka Creek via the MSB is groundwater and all water moving through the MSB passes through the IZ.

Rationale: The sinking of Mud Creek within the IZ indicates that the majority of the water moving on or into the watershed drained by the creek passes through at least part of the IZ as groundwater. The amount of water that escapes via surface flow during high water has already been accounted for in the first assumption.

Assumption: The surface water and groundwater divides are equal to each other.

Rationale: It is probable that a deep regional flow regime exists below the Study Area and that the general direction of groundwater flow in that regime is to the north toward Lake Erie. The shallow regime, however, is controlled by Spring Creek, a tributary to Oatka Creek. Spring Creek acts as a hydrologic boundary and discharge point for shallow flow to the east. It is likely, however, that Spring Creek does not "capture" all the groundwater in the stippled area of Figure 7-2. Some may bypass Spring Creek and flow into the deltaic sediments beneath and south of the Village of Caledonia, which lie within the watershed of the Genesee River. This would have the effect of increasing the VET.

Assumption: The average effective porosity of the water bearing zone used in the basin approach is 10%.

Rationale: Studies of limestone aquifers report porosities in a range of 1 to 30 % (Fetter, 1988). The core logs indicate that the lower two-thirds of the primary water producing unit, the Camillus Formation, appears to be rubbleized and resembles a closely packed gravel. Since the average hydraulic conductivity of a gravel deposit has a median value of .01 cm/sec and the average K value of the middle and lower Camillus is .02 cm/sec, it is reasonable to assume that the deep portion of the Camillus Formation has an effective porosity equivalent to a close packed gravel, about 30% (Fetter 1988). Since the rubbleized portion of the Camillus is approximately one-third of the total thickness of the water producing zone, an effective porosity of 10% for the entire IZ is a reasonable assumption to incorporate into the basin analysis.

Assumption: There is no net change in the storage of surface water or groundwater.

Rationale: This is a valid assumption when dealing with a hydrogeologic system over a long period of time since the system has equilibrated to the existing climatic and geologic conditions.

7.5.2 The Darcy Approach

As an independent approach to calculating an estimate of the VET, a simple groundwater flow calculation employing the Darcy equation was performed. The standard formula for discharge (in porous media) is given as:

$$Q = -KA\ dh/dl$$

where;

- Q = discharge, volume per unit time ($v/t = l^3/t$),
- K = hydraulic conductivity, length per unit time (l/t),
- dh = change in height between two data points, length (l),
- dl = distance between two data points, length (l), and,
- A = the area, square feet, (l^2),

Wells DC-4C and DC-14B best represent the average groundwater gradient (in the contaminated strata) across the IZ. The mean water surface elevation measured in these wells yields an average head differential of 75 feet (i.e. dh = 75 ft). The distance between DC-4C and DC-14B is approximately 20,200 feet (dl = 20,200). The results of multiple slug tests, as reported in Section 5.4, yield an average K value for upper Camillus and Falkirk formation of 0.002 cm/sec (5.67 feet per day). Employing the approximate cross-sectional area of the contaminant plume, 70 feet by 7,000 feet, yields an area of 490,000 sq.ft. With K, dh/dl, and A determined, the discharge through the contaminated area is estimated as 5.67 ft/d x (75/20,200) x 490,000 sq.ft.= 10,315 cu.ft./day.

To calculate the time it will take to replace the water in the area of the contaminant plume, based on this groundwater discharge rate, the volume of the aquifer is multiplied by the porosity of the aquifer and then divided by the discharge. Using an assumed porosity of 5% for the aquifer yields a VET of 131 years.

<u>Assumption and Rationale</u>

Assumption: The average effective porosity of the contaminated water bearing zone used in the Darcy Approach is 5%.

Rationale: The contaminated zone is located within the upper Camillus and lower Falkirk geologic units. Downhole video, caliper logs and visual observation of the core suggest a porosity lower than that found within the middle and lower Camillus Formation (assumed to be 30%). Fractures were much less frequent throughout this section. A value of 5% is conservative in that a lower value 3% (Fetter, 1988), one more typical of slightly fractured limestone, would decrease the VET.

7.5.3 Discussion of Results

The Basin and Darcy approaches yield values that differ by a factor of seven. These values, 18 years and 131 years, provide estimates of the time in which water in different parts of the groundwater system will be replaced. That is, the shorter time period represents the time for the water in the fractures (secondary porosity) to be replaced and the longer time period represents the time for the water in the micropores (primary porosity) to be replaced. In corroboration of this theory, it is known when the spill occurred and approximately when TCE was detected in the wells and springs near Spring Creek. Using this data, it can be estimated that it takes 20 years or less to flush or remove water from the fractures that feed these wells and springs. The 20-year time period represents the maximum time, because contamination may have reached these springs prior to this time. This time period is, however, similar to the time estimated using the basin approach. The VET determined by the basin approach shows that the storativity of the highly fractured middle to lower Camillus governs the flow of water through the basin to Oatka and Spring Creeks. Even though this stratigraphic zone dominates the flow of water through the IZ, it should not be considered as the sole focus for the VET because this zone of the aquifer is generally free of contamination.

The Darcy approach results in a lower VET because the hydraulic conductivity of the contaminated strata is much lower than that of the middle to lower Camillus, which is emphasized in the basin approach. The micropores within the limestone are several orders of magnitude smaller than the apertures of bedrock fractures. Because of this, the rate of water movement through these pores is correspondingly much slower than that through the fractures or macropores, which increases the VET. A 100 foot thick wedge of glacial deposits (deltaic sand and gravel over glacial till) is located south and east of Spring Creek. This deposit probably acts as a hydrologic capture zone that removes water from the upstream basin. If this is the case, more water will move through the Study Area; and therefore, the VET may be shorter than the 131-year estimate.

It should be noted that the VET calculations are estimates of time to naturally replace the volume of water within the IZ. They should not be used to predict the time required to remove contaminants from the IZ, partially because contamination may occur in fractures above the water table. In this case, the time it would take to naturally remove the contamination would be directly dependent upon the amount of time that the saturated surface intersected the contaminated zone. The upper zones of the aquifer may become recontaminated as the zone of saturation rises and intersects contamination within the upper fractures. The net effect is that any contamination residing in the upper fractures will act as a potential source that is reactivated during high water table conditions. This source of contamination will exist until all the source material within the fractures has been flushed out.

In summary, the contamination that resides within the fractures that are currently tapped for water wells will probably clean itself naturally in at least 20 years once a control structure has been set up to remove or isolate the source. Those wells that penetrate the lower Camillus Formation will most likely become clean in a shorter time period, i.e. 8 years. The flushing time is directly proportional to the size of the fractures and the driving head within the fractures. Wells that penetrate rock containing few or no fractures may have contaminants residing in the micropores. Fortunately, because the porosity and storativity of dense carbonate rock is so low, few wells are completed in such zones.

7.6 OVERVIEW AND SUMMARY

The historical evidence, consisting of newspaper reports, a consultant's report (Marshall, 1971), and legal testimony (Marshall, 1992), provides some insight regarding the subsurface transport and distribution of TCE during the weeks and months following the train derailment and chemical spill. This evidence indicates that, although Mud Creek "captured" some contamination and conveyed it to the northeast, some quantity of TCE bypassed the creek and was rapidly conveyed along bedrock fractures toward the southeast.

TCE contamination continues to persist in the overburden/fill in the immediate area of the spill. These materials, therefore, act as a continuing source of groundwater contamination. Non aqueous phase TCE is apparently present in bedrock fractures above and/or below the water table, up to 600 feet from the derailment/spill site. Contaminated groundwater continues to be generated by contact with the NAPL source, and flows seasonally into the Mud Creek valley, and year-round toward Spring Creek. A slug of highly contaminated groundwater is released seasonally during the high-water period. In the area of the spill, groundwater appears to be contaminated at depths from the water table to the upper Camillus Formation.

East of Church Road, uncontaminated groundwater overlies the plume, which appears to be confined to the Bertie and upper Camillus Formations. The plume is approximately 70 feet thick in this area. The base of the plume has not been defined in the area of Spring Street, nor has the southern extent of groundwater contamination been delineated along Route 5, east of Callan Road. The narrowness of the plume at Church Road, and the proximity of contaminated domestic wells to clean domestic wells throughout the Study Area, indicates that high-angle fractures may locally play a significant role in contaminant transport. The major volume of groundwater in the Study Area, however, is probably transmitted via bedding plane fractures.

A volume exchange time (VET) calculation indicates that the natural replacement of a pore volume of groundwater would be between 18 and 131 years. This suggests an approximate "idealized" cleanup time for groundwater present in fractures, and in pores, respectively, once the contaminant source area has either been remediated or hydraulically isolated.

8.0 QUANTITATIVE HUMAN HEALTH EVALUATION

Due to the unique and significant nature of this section, it has been produced separately as Volume II of the Remedial Investigation Report.

9.0 FISH AND WILDLIFE IMPACT ANALYSIS

9.1 INTRODUCTION

This section presents the findings of the Fish and Wildlife Impact Analysis (FWIA) that was performed as part of the Remedial Investigation of the Lehigh Valley Railroad Derailment Site. Both a Step I (Site Description), and the pathway analysis and criteria-specific analysis sections of a Step II (Contaminant-Specific Impact Analysis) FWIA were performed. The findings of the FWIA are presented in the following text.

The objective of Step I of an FWIA (Site Description) is to identify the fish and wildlife resources that exist in the vicinity of a site, or that existed prior to the introduction of spill-related contaminants, and that could potentially be affected by spill-related contaminants. This information is necessary to allow identification of potential pathways of contaminant migration that could impact fish and wildlife resources.

The objective of Step II in the FWIA process is to determine the impacts, if any, of spill-related contaminants on fish and wildlife resources. The pathway analysis evaluates and identifies potential contaminants of concern, sources of contaminants, potential pathways of contaminant migration and the potential for fish and wildlife resources to be impacted by spill-related contaminants. The criteria-specific analysis determines if reported concentrations represent a potential threat to aquatic life and wildlife.

The subject of this FWIA was to determine the potential impact on fish and wildlife resulting from a railroad derailment on December 6, 1970. Two railroad cars containing TCE ruptured and discharged approximately 30,000 gallons of TCE onto the ground. Another car reportedly discharged part of its load of crystalline cyanide onto the ground at an unknown location. Based on the history of the Site, the contaminants of potential concern are TCE and its two principal degradation products, cis-1,2-DCE and vinyl chloride, and cyanide.

Due to the fractured nature of the carbonate bedrock in the vicinity of the derailment area and spill site, TCE originating from the 1970 derailment has moved both vertically and horizontally within the rock and has apparently migrated significant distances from the spill site. The investigation program included the collection of surface water, spring and sediment samples from numerous locations downgradient of, and at distances of up to 4 miles east of the spill site.

The FWIA did not address the entire Study Area because of a variety of factors, including:

- the major surficial features near the spill site (quarries, Mud Creek, etc.);
- the depth of the contamination below the ground surface throughout most of the Study Area, and;
- the length and breadth of the Study Area.

Instead, the FWIA focused on the portions of the Study Area most likely impacted by the contamination. The primary area of investigation was the area in the vicinity of the spill. The second area evaluated in the FWIA was Spring Creek, which is located approximately 4 miles east of the Site. The Spring Creek area was investigated because TCE was detected above NYSDEC groundwater and surface water guidance values in surface water samples and spring samples collected within the Spring Creek drainage system. Additionally, a NYSDEC fish hatchery, the Caledonia State Fish Hatchery, is located on Spring Creek.

9.2 STEP I - SITE DESCRIPTION

The site descriptions presented in the following text include descriptions of the vegetative cover types or habitats, land use, fish and wildlife resources, and the value of the various habitats to fish and wildlife. Additionally, applicable fish and wildlife regulatory criteria are presented.

A complete Step I Site Description was performed for the area around the spill site, and a cover type map was prepared. The Site Description for the Spring Creek area focused on Spring Creek itself, from its headwaters in the Village of Caledonia to the pond at the Genesee Country Inn north of George Street (Route 147). A cover type map was also prepared for the area within a half mile of the Caledonia State Fish Hatchery. However, a description of the vegetative communities was not prepared since Spring Creek and its immediate environs, and not the surrounding upland habitats, is the area of potential concern.

9.2.1 Land Use/Major Vegetative Communities Within One-half Mile of the Site and in the Vicinity of Spring Creek

Cover type maps detailing the major land use/vegetative communities within a one-half mile radius of the spill site and the Caledonia State Fish Hatchery are presented on Plates 5 and 6, respectively. The cover type maps were prepared based on an interpretation /evaluation of aerial photographs, topographic maps and NYSDEC wetland maps. The base maps for the cover type maps were prepared from aerial photographs taken in April 1980. The cover types within a half mile of the spill site, and directly along Spring Creek, were classified using a combination of the New York Heritage Program Classification System (NHPCS, Reschke, 1990) and the U.S. Geological Survey Classification System (Anderson, 1976). Field checking was performed to verify the accuracy of each cover type map.

Where access was possible during the field check of the draft cover type map associated with the spill site, the dominant vegetation in each cover type was identified for areas classified as terrestrial natural (TN) and palustrine (P). The determination of dominance was qualitative, based on visual estimates. Vegetative plots and transects were not used in determining dominance, as these methods are beyond the scope of a Step I analysis. The determination of the dominant vegetation in the cover types associated with the Spring Creek area was limited to Spring Creek itself and the areas directly adjacent to the creek.

Natural areas, TN signifying terrestrial and P as palustrine, identified on the cover type maps with a number were accessible during the field check of the cover type maps. The areas not numbered were either not accessible or were similar in nature to the other areas. The numbers in each area correspond to the numbers and descriptions of dominant vegetation for each area as presented in Table 9-1 and Table 9-2 for the spill site and Spring Creek, respectively.

9.2.1.1 Land Use/Cover Types Within One-Half Mile of the Site

The land use within a one-half mile radius of the spill site is composed primarily of a mixture of residential, industrial (mining) and natural undeveloped land. The Site itself is the area around the former Lehigh Valley Railroad crossing at Gulf Road where the derailment/spill occurred. The immediate location of the spill site consists of a fairly flat and level grade. East and west of the Site the land is also fairly flat, with the exception of a gradual slope to the northeast of where the former Lehigh Valley Railroad line crossed Gulf Road. Gulf Road is fairly level at the spill site and contains shallow drainage ditches along both sides of the road. These ditches drain generally to the east, following the local grade of the road as it descends towards Neid Road, and discharge storm drainage into Mud Creek near Neid Road.

Table 9-1 identifies the dominant vegetation present in the cover types or habitats located within one-half mile of the spill site. The majority of the habitat within a one-half mile radius of the spill site is mixed deciduous forest and successional shrub fields. The cover type numbers presented on Figure 9-1 correspond to the description of dominant vegetation presented in Table 9-1.

Directly north of the spill site is an abandoned quarry pit. The bottom of the quarry is sparsely vegetated with common cottonwood (Populus deltoides), willow species (Salix spp.), honeysuckle species (Lonicera spp.), goldenrod species (Solidago spp.) and andropogon species.

There are a number of successional shrub fields located within a half mile of the Site. The largest area, designated TN1 # 8 on the cover type map, is located approximately 750 feet south of the spill site. The dominant vegetation in this area is red-panicle dogwood (Cornus foemia) and honeysuckle species, with scattered red oak (Quercus rubra), white oak (Quercus alba), sugar maple (Acer saccahrum), and common cottonwood. Understory vegetation includes goldenrod species, wild carrot (Daucus carota), and grass species. A second area of successional shrub field is located approximately 150 feet northeast of the spill site and is designated TN1 # 3 on the cover type map. The dominant vegetation is honeysuckle species, with grass species and wild carrot present in the understory. Fields in this area are separated by hedgerows consisting of red oak and some white oak.

Directly east of the Site is an area of deciduous forest. The dominant vegetation in this area is red oak with shagbark hickory (Carya ovata), and some white oak, with honeysuckle in the understory. There are two areas of deciduous forest located southwest of the Site, and a third located northwest of the Site and adjacent to the abandoned quarry , that are designated TN2D #5 on the cover type map. The dominant vegetation in these areas is red oak, white oak, sugar maple and some hop hornbeam (Carya ostrya), with honeysuckle present in the understory. Another area of deciduous forest, designated TN2D # 2 on the cover type map, is located approximately 1500 feet northeast of the spill site. The dominant vegetation in this area consists of oak (white and red) and sugar maple.

There are two additional areas of mixed deciduous forest and successional shrub field located within a half mile radius of the Site. These areas are designated TN2D/TN1 #'s 7 and 9, respectively on the cover type map. Area # 7 is located approximately 2,200 feet northeast of the Site and consists of red and white oak, sugar maple and honeysuckle thickets. Area # 9 is located north of Gulf Road and west of the abandoned quarry. The dominant vegetation in this area is quaking aspen (Populus tremulodies), common cottonwood, red-panicled dogwood and honeysuckle. There are openings in both the mixed deciduous forest/successional shrub field areas where the primary vegetation is herbaceous.

Mud Creek is the predominant surface water drainage feature located within a half mile of the spill site. Mud Creek generally flows from southwest to northeast. Mud Creek crosses under the old railroad bed through an arch culvert approximately 500 feet east southeast of the spill site. Just north of the culvert, Mud Creek flows into a closed depression having the surface appearance of a sink hole. Mud Creek discharges to Oatka Creek approximately 5,000 feet northeast of the spill site. Prior to flowing into Oatka Creek, Mud Creek enters the gorge pond. The pond is located approximately 3,000 feet northeast of the spill site and was formed by damming Mud Creek at the northern end of the pond. NYSDEC has classified Mud Creek as a Class C stream, which is defined as a stream whose best usage is fishing and whose waters will be suitable for fish propagation and survival. However, Mud Creek is an intermittent stream and is generally dry along a significant portion of its length, i.e. the entire length upstream (south) of the gorge pond, for a substantial part of the year.

9.2.1.2 Land Use/Cover Types in the Vicinity of Spring Creek.

The land use within a one-half mile radius of the Caledonia State Fish Hatchery on Spring Creek is a mixture of residential/commercial, agricultural, and undeveloped natural areas. Spring Creek and the adjacent habitats was the focus of the FWIA in this section of the overall Study Area, since Spring Creek, including the Caledonia State Fish Hatchery and the wetland habitats associated with Spring Creek, are the habitats that could potentially be impacted by spill-related contaminants. Table 9-2 identifies the dominant vegetation present in the cover types or habitats located adjacent to Spring Creek

Spring Creek is spring fed and exhibits a rather consistent flow of water throughout most of the year. Spring Creek flows south to north and discharges to Oatka Creek north of the Village of Mumford. The NYSDEC has classified Spring Creek as a Class C(TS) stream from the Caledonia State Fish Hatchery south, and as a Class C stream from the fish hatchery north to Oatka Creek. The best usage of Class C streams is fishing and these waters shall be suitable to fish propagation and survival. The water quality shall also be suitable for primary and secondary contact recreation, however, other factors may limit the use for this purpose. The (TS) designation indicates that the waters are considered trout waters and are suitable to spawning trout populations.

Spring Creek would best meet the definition of a Rocky Headwater Stream using the New York Natural Heritage Program, Ecological Communities of New York, classification system (Reschke, 1990). These streams are typically characterized by a moderate to steep gradient and cold water that flows over eroded bedrock. Waterfalls and springs may be present. Spring Creek is unique in that the stream is primarily spring fed.

The majority of the habitat adjacent to Spring Creek is forested wetland, with some limited emergent wetland habitat. The cover type numbers presented on Figure 9-2 correspond to the description of dominant vegetation presented in Table 9-2.

Approximately 1,400 feet south of the Caledonia State Fish Hatchery, primarily on the east side of Spring Creek, there is an area of coniferous forested wetland, designated P2 # 1, that is dominated by northern white cedar (Thuja occidentalis) and red maple (Acer rubrum); cattail (Typha spp.) are also present in this area.

Directly south of the fish hatchery, on both sides of Spring Creek, there is an area of mixed deciduous and emergent wetland that is designated P2/P1 # 2. The dominant tree species in this area is green ash (Fraxinus pennsylvanica); the dominant shrubs include silky dogwood (Cornus ammomum), common spice bush (Lindera benzoin), and willow species (Salix spp.). Cattails are the dominant vegetation present in the areas of emergent marsh.

West of the fish hatchery, on the west side of Spring Creek, is an area of deciduous forested wetland designated P2 # 3. The dominant vegetation in this area is common cottonwood (Populas deltoides), American elm (Ulmus americana), with common spice bush in the shrub layer.

North of the fish hatchery, deciduous forested wetlands line both sides of Spring Creek up to Route 147 (George Street) in Mumford. This area is designated P2 # 4 on Figure 9-2. The overstory vegetation present in this area include white oak (Quercus alba), swamp white oak (Quercus bicolor), red maple, green ash and American elm; common spice bush is dominant in the shrub layer.

9.2.2 Wetlands Within One-Half Mile and Two Miles of the Site

There are no New York State regulated wetlands located within a one-half mile radius of the spill site; however, there are two New York State regulated wetlands located within a two mile radius of the spill site. Both of these wetlands, designated CH-27 and CH-28, are located along Oatka Creek. At its closest point, wetland CH-27 is located approximately 4,000 feet north of the spill site, west of the confluence of Mud and Oatka Creek. Wetland CH-28 is located approximately 4,000 feet north-northeast of the spill site. The southernmost extent of wetland CH-28 coincides with the point where Mud Creek discharges to Oatka Creek. As previously stated, New York State regulated wetland CA-1 is located along Spring Creek, approximately 3.9 miles east of the spill site. This area was included in the investigation due to groundwater and surface water data that indicated that spill-related contaminants may have migrated via groundwater to the Spring Creek drainage system. The locations of the NYSDEC regulated wetlands are presented in Figure 9-3.

The geographical distribution of wetlands and the documented movement of groundwater and or surface water indicate that the only two New York State regulated wetlands that could potentially be impacted by spill-related contaminants are wetland CH-28 and CA-1. Potential exposure pathways are discussed in Section 9.6.1.

9.2.3 Wetlands in the Vicinity of Spring Creek

The wetland located along Spring Creek from Route 5 north to Route 147 is regulated by NYSDEC and has been given the designation CA-1. NYSDEC has classified wetland CA-1 as a Class II wetland. NYSDEC has four wetland classifications, I through IV, with Class I representing the most valuable and having the greatest ability to perform wetland functions and to provide wetland benefits. A Class II wetland, such as the wetland located along Spring Creek, represents a high quality wetland that functions as an ecologically significant plant community/habitat, and provides wetland benefits. In order for a wetland to be considered as a Class II wetland, it must have at least one of seventeen characteristics that are enumerated in the Freshwater Wetlands Maps and Classification Regulations (6 NYCCR Part 664.5).

9.2.4 Streams and Related Surface Water Bodies Within One-Half Mile and Two Miles of the Site

The only stream located within one-half mile of the spill site is Mud Creek. As previously stated, Mud Creek is an intermittent stream, classified by NYSDEC as a Class C stream. Mud Creek flows from southwest to northeast and, at its closest point, is located approximately 500 feet east of the spill site. Mud Creek crosses under the old Lehigh Valley railroad bed through an arch culvert approximately 500 feet east southeast of the spill site. Please refer to Section 5.1.1 of this report for additional information on Mud Creek.

With the exception of Oatka Creek, there are no other streams located within a two mile radius of the spill site that could be impacted by spill-related contaminants. The closest point that Oatka Creek comes to the spill site is at its confluence with Mud Creek, approximately 5,000 feet northeast of the spill site. Oatka Creek is classified by NYSDEC as a Class B(T) stream, both upstream and downstream of where Mud Creek discharges to the Oatka Creek. The best usage of Class B waters is for primary and secondary contact recreation and fishing. Class B waters shall also be suitable for fish propagation and survival. The (T) designation indicates that the waters are considered trout waters and are suitable for supporting a trout population.

9.2.5 Streams and Related Surface Water Bodies in the Vicinity of Spring Creek

As previously stated, Spring Creek has been included in the FWIA. Although this stream is located approximately 4 miles east of the spill site, groundwater samples and spring samples indicate that spill-related contaminants may have migrated as far as the Spring Creek drainage. Spring Creek is the only surface water body in the area, until it flows into Oatka Creek north of the Village of Mumford.

9.3 RESOURCE CHARACTERIZATION WITHIN ONE-HALF AND TWO MILES OF THE SITE AND IN THE VICINITY OF SPRING CREEK

Resource characterization consists of determining the wildlife species that may potentially utilize, or have been determined to utilize, the habitats identified in the previous sections as existing within one-half mile of the Site. Also, any known species of concern (i.e., endangered, threatened, etc.) or significant habitats that may exist within two miles of the Site are identified. Additionally, the general quality of the habitats that are located within one-half mile of the Site and their ability to provide for the needs of the species that may utilize the habitats is discussed. Areas of observed vegetative stress, leachate seeps, documented evidence of fish and/or wildlife mortality and any known population impacts related to spill-related contaminants are presented.

9.3.1 Endangered, Threatened or Special Concern Fish and Wildlife Species or Significant Habitats or Rare Plant Species

The United States Fish and Wildlife Service (USFWS), the NYSDEC Wildlife Resources Center and the NYSDEC Region 8 Office were contacted regarding the known occurrence of endangered, threatened, or special concern fish and wildlife species or significant habitats located within a two mile radius of the Site. The USFWS indicated that there are no known occurrences of federally listed endangered or threatened wildlife species located within a two mile radius of the Site.

There are no documented occurrences of a New York State endangered, threatened or rare plant species located within a one-half mile radius of the spill site. There are, however, four threatened and five rare plant species located within a two mile radius of the spill site, as listed below.

The four Threatened Species are:

- Trollius laxus spp.- Spreading globeflower;
- Hydrastis canadensis- Golden-Seal;
- Desmodium ciliare- Tick-Trefoil; and
- Desmodium glabellum- Tall Tick-Clover.

The five Rare Species are:

- Jeffersonia diphylla - Twin-leaf;
- Lathyrus ochroleucus- Wild-pea;
- Carex Willdenowii- Willdenow sedge
- Agrimonia Rostellata- Woodland Agrimony Plant; and
- Triglochin pallustre- Marsh Arrow-Grass Plant.

Due to the sensitive nature of these species, the New York State Natural Heritage Program will not allow release of specific location information. Therefore, the exact location of these species with respect to the spill site is not presented. Spill-related contaminants are not considered a threat to any of these species at the locations identified in the New York State Natural Heritage Program file review. This conclusion is based on the reported location of observed species with respect to the Site, the potential contaminant migration pathways, and environmental chemical data.

There were no known threatened, endangered or rare plant species identified as occurring along Spring Creek.

9.3.2 Fish and Wildlife Species Potentially Using Habitats Within a One-Half Mile Radius of the Spill Site and Habitats Associated With Spring Creek

Fish, wildlife (mammal, amphibian and reptile), and bird species that could potentially utilize the habitats within a one-half mile radius of the spill site and the habitats associated with Spring Creek, for at least a portion of their life cycle, are listed in Tables 9-3, 9-4 and 9-5, respectively. These lists are not meant to indicate that these species can always be found, or that all will be present at one time within one-half mile of the spill site. These lists were prepared following a limited field evaluation of the habitats and review of available literature; they are not the result of a site-specific population survey. Actual population surveys are complex and time intensive and beyond the scope of a Step I baseline evaluation.

Many wildlife species are mobile and generally require a range of habitat types to meet their life cycle requirements. In addition, many species will only use the area within one-half mile of the Site for a portion of their life requisites. Thus, all the species identified on these lists were not actually observed within a one-half mile radius of the spill site or in the vicinity of Spring Creek.

During the field checking of the cover type map on November 9, 1993, the species listed below were observed within one-half mile of the spill site or along Spring Creek:

- Black-capped Chickadee
- Cardinal
- Common Crow
- Red-tailed Hawk
- Wild Turkey
- Blue-jay
- Canada Goose
- Mallard Duck
- Red-winged Blackbird
- White-tailed Deer

9.4 GENERAL HABITAT QUALITY WITHIN ONE-HALF MILE OF THE SITE AND IN THE VICINITY OF SPRING CREEK

The terrestrial undeveloped natural habitats located within a one-half mile radius of the spill site generally represent quality wildlife habitats. The undeveloped habitats located within a one-half mile radius of the Site are generally connected to and associated with a larger area of undeveloped habitat. A commonly accepted ecological tenet is that a large area can support a greater number of species than a small one.

The mixture of successional shrub field and deciduous forest provides a mixture of habitat types available to wildlife and increases the plant diversity of the area. Since all animals are ultimately dependent on plants, either directly or indirectly, an increase in the diversity of plant species results in a higher quality habitat. Additionally, the transition of shrub forest to deciduous forest creates edge habitat. An increase in the quantity of edge habitat has also been used as a measure of habitat quality with respect to species that require a variety of habitats. Generally, habitat quality increases with an increase in edge habitat. Species such as song birds, ruffed grouse, cottontail rabbits and white-tailed deer will benefit from a high degree of edge habitat.

Within the successional shrub field areas, there are dense thickets of honeysuckle. These thickets have created monotypic stands of honeysuckle, which has resulted in a decrease in plant diversity. Where these stands have formed, there is an overall decrease in habitat quality.

Mud Creek is the only surface water feature located within a one-half mile of the Site. As previously stated, Mud Creek is an intermittent stream that is dry for a significant period of the year and, as such, represents a poor quality aquatic habitat. Aquatic-related fauna utilizing Mud Creek are limited to species that do not require a permanent supply of running water.

Spring Creek, located approximately four miles east of the spill site, represents a high quality aquatic habitat. The stream is spring fed and flows year round at a relatively constant temperature and flow rate. The stream supports a self-sustaining trout population. The forested and limited emergent wetlands provide habitat for a wide variety of aquatic and terrestrial species. Water fowl and white-tailed deer were observed in this area. The waters from Spring Creek are used by the Caledonia State Fish Hatchery for its fish rearing raceways.

9.5 APPLICABLE FISH AND WILDLIFE REGULATORY CRITERIA

The appropriate Site-Specific Criteria (SSC) that may potentially be applicable to the Site will be partially dependent on the selected remedial alternative (if any). This section presents the fish and wildlife SSC that should be considered. SSC will be further discussed in the Feasibility Study.

Fish and wildlife-related SSC that may be applicable to the Site are presented below:

- Clean Water Act, 233 U.S.C. 1261 et seq. Sec. 404 regulates the discharge of pollutants into wetlands and other water bodies, including dredged or fill materials;
- The Freshwater Wetlands Act (Article 24 of the Environmental Conservation Law) and the Freshwater Wetlands Implementing Regulations (6 NYCRR Parts 663 and 664) are designed to protect wetlands. Only wetlands that have been mapped by the State of New York are regulated;
- Executive Order 11990, Protection of Wetlands. This order recognized the value of wetlands and directed federal agencies to minimize the degradation, destruction and loss of wetlands;
- Endangered Species Act (87 Stat. 884, as amended; 16 U.S.C. 1531 et seq.);
- Fish and Wildlife Coordination Act;
- NYSDEC, Division of Water Technical and Operational Guidance Series (1.1.1) Ambient Water Quality Standards and Guidance Values, October 1993;

- NYSDEC, Water Quality Regulations for Surface Waters and Groundwaters, 6 NYCRR Parts 700-705;
- NYSDEC, Technical Guidance for Screening Contaminated Sediments, November 1993; and
- Article 15, Title 5 - Environmental Conservation Law, Protection of Waters, and Part 608, Use and Protection of Waters.

9.6 STEP 2 - CONTAMINANT-SPECIFIC IMPACT ANALYSIS

This section evaluates pathways through which wildlife could potentially be exposed to spill-related contaminants. This evaluation includes the identification of habitats that could potentially be impacted by the contaminants, the possible food chain contamination pathways, and impact to fish/wildlife, if any.

As previously mentioned, this investigation is associated with a railroad derailment that resulted in the discharge of TCE and cyanide to the environment. Therefore, the contaminant-specific impact analysis focuses on TCE and its associated degradation products; 1,2-dichloroethene (primarily cis-1,2-DCE), vinyl chloride, and cyanide. These compounds are considered to be the compounds of potential concern.

9.6.1 Pathway Analysis

The nature of the spill site, length of time between the initial spill and this investigation, physical characteristics of the contaminants of concern and the migration of TCE indicate that the surface water and sediments associated with the Mud Creek drainageway, springs east of the Site, and Spring Creek are the habitats that could potentially be impacted by spill-related contaminants. Additionally, because the surface water and groundwater discharge through springs located in the Mud Creek channel ultimately flows into the gorge pond and then into Oatka Creek, these two features could also be impacted.

Wildlife could potentially be exposed to spill-related contaminants via contact with contaminated surface water or groundwater via discharge through springs, and contaminated sediments. This contact could be associated with Mud Creek, the gorge pond, Spring Creek or Oatka Creek. Additionally, the Caledonia State Fish Hatchery uses Spring Creek as a water source for the hatchery operation. The greatest potential impact would be to aquatic-related species: principally, fish, macroinvertebrates and amphibians. The physical properties of the spill-related chemicals indicate that bioaccumulation should not be a significant factor. Therefore, wildlife consumers of potentially impacted fish, macroinvertebrates and/or amphibians are not considered at risk.

Mud Creek flows past the spill site approximately 500 feet to the east. The creek enters a closed depression that has the surface appearance of a sink hole. This depression contains ponded water during high flow periods. Downstream of the Site within the Mud Creek channel are several springs. Additionally, Mud Creek flows into the gorge pond located approximately 3,000 feet northeast of the spill site.

Mud Creek is an intermittent stream that is dry throughout a significant portion of the year; additionally, the springs located in the Mud Creek drainageway are also dry during parts of the year. Because of the intermittent nature of Mud Creek, its does not represent a significant aquatic habitat. However, it can act as a conduit for spill-related contaminants to reach the gorge pond and, potentially, Oatka Creek. As part of the investigation, samples were collected from a number of locations in Mud Creek, including spring samples, sediment samples and surface water samples. Surface water and sediment samples were also collected from the gorge pond.

Groundwater analytical data and spring sample data indicated that spill-related contaminants have migrated to the east of the spill site. A number of samples have been collected from springs located in the Spring Creek area. Surface water and sediment samples have also been collected from Spring Creek.

9.6.2 Criteria-Specific Analysis

This section compares the surface water and sediment analytical results collected from the Mud Creek drainage basin and from the Spring Creek area with available Criteria-Specific Standards (CSS). As previously stated, the four compounds of potential concern are TCE, its two principal degradation products, cis-1,2 DCE and vinyl chloride, and cyanide. Review of the surface water and sediment data indicated that vinyl chloride was not detected at or above the laboratory reporting limit in any of the surface water or sediment samples, therefore, this compound is not a compound of concern with respect to this FWIA and has not been further evaluated. Available data also indicated that very little cis-1,2-DCE was detected in the sediment and surface water samples. The low frequency of detection of cis-1,2-DCE and vinyl chloride indicated that little or no abiotic or biotic degradation of the TCE is occurring.

The surface water criteria-specific standard for cyanide is the NYSDEC surface water standard for free cyanide (5.2 μg/l), which is based on protection of aquatic life. However, the NYSDEC Part 703 Regulations do not have any aquatic toxicity-based standards or guidance values for TCE or cis-1,2-DCE. Therefore, surface water guidance values were calculated following the guidance presented in NYSDEC Part 701.10 (d)(2). Table 9-6 presents a summary of ecotoxicity data obtained from a Hazardous Substance Data Base search (HSDB), and an Aquatic Information Retrieval (AQUIRE) database search, and presents a calculated aquatic-based surface water guidance value. For TCE, the calculated value is based upon information from aquatic insects, fish species and information on two amphibians. Since toxicity data for these forms of aquatic wildlife indicated similar toxicities, the data were averaged to develop one aquatic-based surface water standard. The calculated guidance value was 1,217 μg/l for TCE and 4,050 μg/l for cis-1,2-DCE. These calculations were based on available acute toxicity data and application of an acute toxicity to chronic toxicity factor of 0.03, following the NYSDEC guidelines (701.10 (d)(2)).

Cell multiplication inhibition tests performed on protozoa and green algae using TCE, indicated that inhibition was observed at concentrations greater than 960,000 μg/l and 1,000,000 μg/l, respectively. However, the conditions under which these studies were performed were not specified.

Reported bioconcentration factors for TCE and cis-1,2-DCE are 17-39, and 15, respectively. Based on these bioconcentration factors, neither compound should significantly bioaccumulate in aquatic organisms. Cyanide, which will react with water to form hydrogen cyanide, is miscible with water and will not bioaccumulate. However, cyanide can form complex cyanide metal complexes, some of which will bioaccumulate.

Sediment criteria were calculated following the procedures presented in the NYSDEC Technical Guidance for Screening Contaminated Sediments. TCE is the only compound for which NYSDEC has derived sediment criteria, and this is based on protection of Human Health from bioaccumulation effects from ingestion of aquatic life. Sediment criteria for TCE and cis-1,2-DCE were derived for protection of fish propagation and survival following the NYSDEC criteria; this derivation is presented below. The lowest concentration of organic carbon detected (2.3 percent; TOC concentration from the SED 14B and SED 14D Spring Creek area samples) was used in calculating the sediment criteria. This will result in a conservative estimate of the sediment criteria for all the sediment samples collected and analyzed. No sediment criteria were derived for cyanide. The sediment criteria is based on an equilibrium partitioning methodology that is only applicable to non-polar organic compounds. Cyanide is a polar inorganic compound. Currently there are no algorithms available for deriving sediment criteria for polar compounds.

Aquatic Life Chronic Toxicity Sediment Criteria

SC = WQC x Kow x fOC

where

SC = Calculated Sediment Criteria Value
WQC = Derived water criteria value
Kow = Octanol water partition coefficient
fOC = Site-specific organic carbon concentration (23 gOC/kg).

1. TCE

SC = 1,217 μg/l x 195 l/kg x 1kg/1000g OC x 23 gOC/kg
SC = 5,458 μg/kg

2. cis-1,2-DCE

SC = 4,050 μg/l x 72 l/kg x 1kg/1000gOC x 23 gOC/kg
SC = 6,707 μg/kg

9.6.2.1 Mud Creek Drainageway

Analytical results for surface water samples collected from Mud Creek are summarized in Table 9-7. Plate 2 shows the location of the sampling points. As previously described, Mud Creek is an intermittent stream and does not represent a significant aquatic habitat for species requiring a permanent supply of water. However, comparison of the surface water analytical results with the calculated TCE guidance value based on protection of aquatic life (1,217 μg/l) indicated that all Mud

Creek drainageway spring and surface water concentrations were below this value. The highest TCE concentration detected was 560 μg/l.

All of the spring samples in the Mud Creek drainageway exhibit surface water TCE concentrations that exceed the NYSDEC surface water guidance value for TCE of 11 μg/l, which is based on protection of human health from ingestion of fish. Two surface water samples were collected from the gorge pond. Sample SW-6B, which was collected on the south side of the dike closest to the Mud Creek discharge to the pond, exhibited a TCE concentration (29 μg/l) that exceeded the NYSDEC surface water guidance value for protection of human health from fish ingestion. A second sample, collected on the south side of the dam, exhibited a concentration (6μg/l) that was below the guidance value. Both concentrations were well below the calculated value of 1,217 μg/l for protection of aquatic life.

Analytical data from the Mud Creek drainageway indicate that the reported TCE concentrations do not represent a threat to aquatic life. Data from cell inhibition studies performed on protozoa and green algae indicate that these lower species would not be impacted by concentrations detected in the Mud Creek drainageway. Data from the surface water sample collected at the outlet of the gorge pond indicate that the TCE concentrations from the springs in the Mud Creek drainageway are rapidly diluted with distance from the springs. Data indicate that TCE from the Mud Creek drainageway should not impact Oatka Creek.

Cis-1,2-DCE was not detected in any Mud Creek drainageway water samples at a concentration above the calculated value (4050 μg/l) for protection of fish. With the exception of one sample from Spring 20 (6 μg/l), one sample from Spring 20A (6 μg/l), and one sample from Spring 4 (1μg/l), cis-1,2-DCE was not detected in any sample at or above the laboratory reporting limit. The data indicate that cis-1,2-DCE is not a concern in the Mud Creek drainageway surface water samples.

With the exception of one cyanide result from Spring 3 (10.2 μg/l) cyanide was not detected at or above the laboratory reporting in any Mud Creek drainageway surface water sample. The December 1992, Spring 3 cyanide value of 10.2 μg/l exceeded the surface water standard for protection of aquatic life of 5.2 μg/l. However, a sample collected from Spring 3 in April 1994 was non-detect at 10 μg/l. Available data indicate that cyanide is not a significant concern in the surface water in the Mud Creek drainageway. However, the aquatic standard of 5.2 μg/l is below the method practical quantitation limit of 10 μg/l. Therefore, an absolute definitive evaluation of any potential impact of cyanide on surface water quality cannot be performed.

Mud Creek drainageway sediment sample analytical results are summarized in Table 9-8. Sediment samples were collected from the Mud Creek drainageway and from the gorge pond. Comparison of the Mud Creek sediment sample TCE and cis-1,2-DCE concentrations to sediment criteria revealed that, with the exception of the December 1992 SED-2 sample, all concentrations were below the TCE and cis-1,2-DCE sediment criteria. The December 1992 SED-2 TCE concentration of 71 μg/kg exceeded the TCE sediment criteria for protection of human health from bioaccumulation effects via ingestion of aquatic life. However, the SED-2 sample was collected from the Mud Creek channel near the spill site. As previously mentioned, this portion of Mud Creek is an intermittent stream that is dry for a significant portion of the year and, therefore, does not represent a viable aquatic habitat. The NYSDEC sediment criteria based on protection of human health from toxic effects from bioaccumulation is not applicable to this sampling location.

The available sediment data from the Mud Creek drainageway indicate that TCE and cis-1,2-DCE concentrations do not represent a threat to the propagation and survival of fish, and that TCE concentrations do not represent a significant threat to human health based on the toxic effects associated with bioaccumulation.

9.6.2.2 Spring Creek Drainageway

Sample locations in the Spring Creek drainageway included two surface water sampling points (SW-FH1 and SW-14) directly in the stream and two springs (SPR-11 and SPR-18) collected in the headwaters of Spring Creek. Additionally, samples were collected from four other springs (SPR-12, SPR-L23S, SPR-21 and SPR-26) and one other surface water sample (SW-15), all of which are located in the Spring Creek drainageway.

Surface water sample location SW-FH1 is located in Spring Creek, just upstream of the Caledonia State Fish Hatchery. Sample location SW-14 is located behind (north of) the Genesee Country Inn, north of Route 147, where Spring Creek enters a ponded area. This pond is located approximately 400 feet south of the point where Spring Creek discharges to Oatka Creek. Spring sampling locations SPR-11 and SPR-18 are located in the headwaters of Spring Creek, approximately 500 feet north of Route 5, on the west and east side of Spring Street, respectively.

Spring Creek drainageway surface water analytical data for the spill-related contaminants are summarized in Table 9-9. Analytical results revealed that all SW-FH1, SW-14, SPR-11 and SPR-18 TCE results were less than both the NYSDEC surface water guidance value of 11 μg/l (protection of human health from toxic effects associated with consumption of aquatic life) and the calculated guidance value (1,217 μg/l) based on protection of aquatic life. No cis-1,2-DCE, vinyl chloride or cyanide was detected in any of these samples at or above the laboratory reporting limit. The data indicate that surface water quality in Spring Creek itself, has not been significantly impacted by spill-related contaminants. The data also indicates that spill-contaminants have not impacted Oatka Creek via the Spring Creek pathway. However, the method practical quantitation limit for cyanide (10 μg/l) is greater than the surface water standard of 5.2 μg/l. Therefore, an absolute definitive evaluation of the impact of cyanide on surface water quality cannot be performed.

The Caledonia State Fish Hatchery, which uses water from Spring Creek in its fish rearing ponds, has not observed any unusual fish kills (verbal communication: Mr. Allan Mack, Hatchery Manager). However, the water from Spring Creek is aerated prior to use to increase dissolved oxygen concentrations and reduce nitrogen concentrations. This aeration would tend to reduce TCE concentrations in the raw Spring Creek water.

With the exception of SPR-12 and the one sample from SPR-21, all other spring and surface water sample TCE analytical results were less than both the NYSDEC guidance value (11μg/l) and the calculated guidance value (1,217 μg/l) for protection of aquatic life. Cis-1,2-DCE and vinyl chloride were not detected in any of the samples at or above the laboratory reporting limit.

Samples from SPR-12 have consistently exhibited TCE concentrations (range 46 μg/l to 100 μg/l) that have exceeded the NYSDEC guidance value of 11 μg/l, (protection of human health from toxic effects associated with the consumption of aquatic life). However, the SPR-12 location does not represent a viable recreational fishing location. SPR-12 is a spring located approximately 500 feet west of Spring Creek. Although the groundwater discharge from SPR-12 does drain toward and ultimately into Spring Creek, TCE concentrations are significantly reduced due to dilution and/or volatilization between the spring and Spring Creek and by the waters of Spring Creek itself. All SPR 12 TCE concentrations were below the calculated value for protection of aquatic life and were below the concentration reported in the literature for inhibition of cell multiplication in protozoa and green algae.

Spring SPR-21 has been sampled only once (April 1994), this spring was dry during subsequent sampling events. The April 1994 sample from this location exhibited a TCE concentration of 1,900 μg/l, which exceeded both the NYSDEC guidance value (11 μg/l) for protection of human health associated with the consumption of aquatic life and the calculated guidance value (1,217 μg/l) for protection of aquatic life. This spring does not represent a viable recreational fishing area due to location and the intermittent nature of the spring. Spring 21 is located approximately 600 feet north of Route 5 and 400 feet west of Spring Street. Although outflow from this spring may ultimately reach Spring Creek, data from Spring Creek indicate that concentrations in the creek are not of concern, most likely due to volatilization and dilution.

Sediment analytical results for the spill-related contaminants from samples associated with Spring Creek are summarized in Table 9-10. In December 1992, a sample collected from the pond north of the Genesee Country Inn (SED-14) exhibited a TCE concentration of 170 μg/kg, which exceeded the site-specific calculated sediment criteria value (46 μg/kg) for protection of human health from toxic effects associated with bioaccumulation. The value was below the calculated sediment criteria value (5,458 μg/kg) for protection of aquatic life. However, TCE was not detected in four sediment samples collected from this pond in November 1993. The November 1993 samples were collected from two locations in the pond; at each location, a sample from 0-6 inches and a sample from 12 to 18 inches was collected. The data indicate that the sediments in the pond have not been significantly impacted with respect to spill-related contaminants. Cis-1,2-DCE and vinyl chloride were not detected in any of the samples at or above the laboratory reporting limits. Cyanide was not detected in the December 1992 sediment sample; the November 1993 sediment samples were not analyzed for cyanide.

9.7 OVERVIEW AND SUMMARY

The FWIA focused on the portions of the overall Study Area most likely to have been potentially impacted by the contamination derived from the derailment/spill. The primary area of investigation was the spill site itself. A second area investigated was Spring Creek, located approximately four miles east of the Site. The primary contaminants of potential concern were TCE and its two primary degradation products, vinyl chloride and cis-1,2-DCE, and cyanide.

The Step I Site Description and associated tasks revealed that the habitats that could potentially have been impacted by spill-related contaminants consisted of the Mud Creek drainageway including the gorge pond, Oatka Creek, the Spring Creek drainageway including the springs located along Spring Creek and the Caledonia State Fish Hatchery.

The Criteria-Specific Analysis consisted of an evaluation of the available environmental analytical results and comparison with applicable surface water and sediment standards. A review of the data indicated that TCE was the predominant compound detected in environmental media. Vinyl chloride was not detected in any environmental sample. There are no promulgated aquatic toxicity based standards available for TCE or cis-1,2-DCE. Therefore, surface water guidance values were calculated following guidance presented in NYSDEC Part 701.10 (d)(2). Sediment criteria were calculated using the derived surface water guidance values and the NYSDEC Technical Guidance for Screening Contaminated Sediments.

Comparison of the spring and surface water analytical results from the Mud Creek and Spring Creek drainageways to published and derived Criteria-Specific Standards, indicated that reported TCE concentrations are below the calculated guidance value for the protection of aquatic life (1,217 μg/l) and that spill-related contaminants have not impacted water quality with respect to aquatic life. Data from the gorge pond located in the Mud Creek drainageway and from Spring Creek indicate that water quality in Oatka Creek would not be adversely impacted by spill-related contaminants via discharge of water from these two areas.

Sediment data from the gorge pond located in the Mud Creek drainageway and the pond located north of the Genesee Country Inn on Spring Creek indicated that the sediments in these ponds have not been significantly impacted by spill-related contaminants.

10.0 NEW YORK STATE STANDARDS, CRITERIA AND GUIDANCE

10.1 INTRODUCTION

The requirements set forth below have been preliminarily identified as applicable or relevant and appropriate "New York State Standards, Criteria, and Guidance" as defined in 6 NYCRR Part 375, Inactive Hazardous Waste Disposal Site Remedial Program, May 1992. NYSDEC program guidance (TAGM HWR-90-4030, May 1, 1990) refers to the same requirements as "Standards, Criteria and Guidelines" (SCGs). SCGs also include federal standards that are more stringent than State Standards, Criteria and Guidelines. Remedial activities for a site must comply with the substantive portions of a requirement or regulation, but need not comply with the administrative requirements of State permits.

SCGs represent minimum requirements that a remedy must satisfy, although SCGs may be waived if one or more of the following circumstances applies:

- the proposed action is only part of a complete remedial program that will conform to such standard or criterion upon completion;
- conformity to such standard or criterion will result in greater risk to the public health or to the environment than the alternatives;
- conformity to such standard or criterion is technically impractical from an engineering perspective;
- the remedial program will attain a level of performance that is equivalent to that required by the standard or criterion through the use of another method or approach; or
- the State has not consistently applied a State requirement in similar circumstances involving other remedial actions within the State.

SCGs may be specific to either the site location, or the contaminants present, or the remedial actions planned at a site. Location-specific SCGs may apply due to the geographical location of a site or its physical setting (e.g., in a wetland). Contaminant-specific SCGs may apply due to the contaminants present or their concentrations, and typically include standards for environmental media and concentration levels governing land disposal. Action-specific SCGs apply to on-site activities and may include design standards, discharge limits, or treatment requirements. These three types of SCGs are individually discussed below.

In addition, State guidance documents and other unpromulgated criteria are "to be considered" (TBC) and used to aid in the design and selection of a remedial alternative. TBCs are also discussed below.

10.2 LOCATION-SPECIFIC SCGs

Location-specific SCGs are requirements that apply to remedial actions due to the location of a site. Table 10-1 presents location-specific SCGs that may be potentially applicable to the Lehigh Valley

Railroad Derailment Site. In addition to those SCGs listed, local zoning ordinances and building codes must be considered.

The Lehigh Valley Railroad Derailment Site location requires identification of SCGs relative to surface water and groundwater. Location-specific SCGs relating to Marine Habitat Protection, and Coastal Zone Management are neither applicable nor relevant and appropriate.

The Freshwater Wetlands Maps and Classification Regulations set forth in 6 NYCRR Part 664 define areas considered to be wetlands by the State. State wetland laws require an area to be at least 12.4 acres, or to be of unusual local significance, as determined by the Commissioner pursuant to ECL 24-0301, to be considered a wetland. The Lehigh Valley Railroad Derailment Site does not contain any wetlands regulated by state or federal regulations.

10.3 CHEMICAL-SPECIFIC SCGs

Chemical-specific SCGs are health or risk-based numerical standards for the concentration of chemical contaminants that may be present in environmental media (air, water, soil, sediment, etc.). New York State has also adopted standardized methodologies that result in the determination of a concentration limit for chemical contaminants in environmental media, which may also serve as target cleanup concentrations. The following sections discuss chemical-specific SCGs with respect to groundwater, surface water, and sediment. Chemical-specific SCGs for soil are not addressed in this report; remediation of the contaminated soil is the subject of a separate, focused feasibility study that will be completed by NYSDEC.

10.3.1 Groundwater and Surface Water

Chemical-specific Federal and State SCGs relative to water are presented in Table 10-2. State groundwater standards are applied at the point of compliance. The point of compliance, defined by NYCRR 373-2.6(f), is the downgradient limit of the waste management area.

Nearby surface waters including portions of Mud Creek, Spring Creek, and numerous springs in the area downgradient from the Site have been sampled and contamination attributable to the Site has been detected.

The Quantitative Human Health Evaluation (Volume II of this report) presents a comparison of groundwater contaminant concentrations to the state drinking water standards. Section 6.0 of this report discusses chemicals detected in the groundwater at concentrations in excess of the NYSDEC groundwater standards.

10.3.2 Sediment

There are no promulgated federal or state SCGs for sediments. However, the State has recommended cleanup criteria that are presented in the NYSDEC's "Draft Cleanup Policy and Guidelines," 1991. The Quantitative Human Health Evaluation and Section 6.0 of this report discuss the contamination present in the sediment with respect to State's sediment cleanup criteria. This risk analysis provides guidance in determining the need for remediation of these sediments.

10.4 ACTION-SPECIFIC SCGs

Action-specific requirements set controls or restrictions on the design, performance and implementation of remedial actions taken at a site. For example, RCRA requirements will be applicable if the remediation constitutes treatment, storage or disposal of a hazardous waste as defined under RCRA. Other examples of action-specific requirements are Clean Water Act standards for discharge of treated groundwater and New York State regulations 6 NYCRR Part 703, which establishes surface water and groundwater quality standards and groundwater effluent standards.

Since action-specific SCGs apply to discrete remedial activities, their evaluation is presented with the detailed analysis of alternatives for each retained alternative. The following action-specific SCGs are potentially applicable to the Lehigh Valley Railroad Derailment Site:

State:

- New York State regulations regarding water quality standards and discharge limitations (6 NYCRR Parts 700 - 703);
- New York State RCRA Standards for the Design and Operation of Hazardous Waste Treatment Facilities (i.e., landfills, incinerators, tanks, containers, etc.) Minimum Technology Requirements (6 NYCRR Parts 370-372);
- New York State RCRA Closure and Post-Closure Standards (Clean Closure and Waste-in-Place Closures) (6 NYCRR Part 372);
- New York State RCRA Generator and Transporter Requirements for Manifesting Waste for Off-Site Disposal (6 NYCRR Parts 364 and 372);
- New York State Land Disposal Restrictions (6 NYCRR Part 376)
- New York State Sanitary Code, Chapter 1, Subpart 5.1, which regulates public water supplies; and
- New York State Air Emission Requirements (VOC Emission for Air Strippers and Process Vents, General Air Quality) (6 NYCRR Parts 200-212).

Federal:

- RCRA Subtitle C Hazardous Waste Treatment Facility Design and Operating Standards for Treatment and Disposal Systems, (i.e., landfills, incinerators, tanks, containers, etc.) (40 CFR 264 and 265) (Minimum Technology Requirements);
- RCRA Subtitle C Closure and Post-Closure Standards (40 CFR 264, Subpart G);
- RCRA Regulations on Land Disposal Restrictions (40 CFR 268);
- RCRA Groundwater Monitoring and Protection Standards (40 CFR 264, Subpart F);
- RCRA Generator Requirements for Manifesting Waste for Off-Site Disposal (40 CFR 263);
- RCRA Transporter Requirements for Off-Site Disposal (40 CFR 270);
- DOT Rules for Hazardous Materials Transport (49 CFR 107,171.1-171.500);
- Occupational Safety and Health Standards for Hazardous Responses and General Construction Activities (29 CFR 1904, 1910, 1926); and
- National Emission Standards for Hazardous Air Pollutants (NESHAPS) (40CFR 61).

10.5 POTENTIAL "TO-BE-CONSIDERED" GUIDANCE

There are instances when SCGs do not exist for a particular chemical or remedial action, or the existing SCGs are not protective of human health and the environment. In these instances, other state and federal criteria, advisories and guidance may be used to aid in the design and selection of a remedial alternative for a site. The following "to-be-considered" criteria may be relevant to the Lehigh Valley Railroad Derailment Site:

State:

- New York State Underground Injection/Recirculation at Groundwater Remediation Sites (Technical Operating Guidance Series (TOGS) 7.1.2);
- New York State Analytical Detectability for Toxic Pollutants;
- New York State Toxicity Testing for the SPDES Permit Program (TOGS 1.3.2);
- New York State Regional Authorization for Temporary Discharges (TOGS 1.6.1);
- New York State Air Guidelines for the Control of Toxic Ambient Air Contaminants (Air Guide 1);
- New York State Office of the State Comptroller, guidelines regarding the financing of public water supply districts;
- Fugitive Dust Suppression and Particulate Monitoring Program at Inactive Hazardous Waste Sites (TAGM 4031); and,
- Selection of Remedial Actions at Inactive Hazardous Waste Sites (TAGM 4030).

Federal:

- Safe Drinking Water Action National Primary Drinking Water Regulations, Maximum Contaminant Level Goals (MCLGs);
- Proposed Maximum Contaminant Levels (50 Federal Register 46936-47022);
- Proposed Federal Air Emission Standards for Volatile Organic Control Equipment (52 Federal Register 3748) (air stripper controls);
- USEPA Drinking Water Health Advisories;
- USEPA Health Effects Assessment (HEAs);
- TSCA Health Data;
- Toxicological Profiles, Agency for Toxic Substances and Disease Registry, U.S. Public Health Service;
- Policy for the Development of Water-Quality-Based Permit Limitations for Toxic Pollutants (49 Federal Register 9016);
- Cancer Assessment Group (National Academy of Science Guidance);
- Groundwater Classification Guidelines;
- Groundwater Protection Strategy;
- Waste Load Allocation Procedures; and,
- Fish and Wildlife Coordination Act Advisories.

11.0 CONCLUSIONS

The following conclusions are presented in the order of the work performed and/or by the order of their discussion in the report, not necessarily by subject matter. The conclusions pertain primarily to the results of Phase C of the Remedial Investigation.

1. An extensive drilling and coring program revealed that the Site and Study Area are underlain by a thin (usually less than 10 feet) layer of unconsolidated deposits of glacial origin. The remedial investigation focused on the underlying bedrock strata, which include Devonian limestones of the lower Onondaga and Bois Blanc Formations, and Silurian dolomites of the Akron, Bertie, Camillus, and upper Syracuse Formations. These strata dip to the south at rates of between 50 and 75 feet per mile. An unconformity, representing the non-deposition or erosion of nearly the entire lower Devonian section was identified within the Study Area. Where present, the unconformity separates the middle Devonian Bois Blanc from either the upper Silurian Akron Formation or an upper member of the Bertie Formation (Williamsville or Scajaquada).

2. The field GC screening program for volatile organic compounds performed during the drilling program was successful in delineating the relative level of volatile organic compounds in each groundwater zone tested, thereby providing a basis for determining the number of wells to be installed at each drilling location, and their completion intervals. The data were also useful with respect to the site-specific health and safety program, and in determining the disposition of drill cuttings and purge water collected during the drilling program.

3. A suite of downhole geophysical and video logs was collected from the deepest boring at each well cluster with the exception of locations DC-15, DC-16 and DC-17. The information from the logs was used to assist in the identification of stratigraphic units and in the delineation of potential water-bearing fractures in the subsurface. While the gamma, caliper, and video logs were extremely useful in characterizing subsurface conditions, the fluid (temperature and resistivity) logs proved to be less useful. Together with the bedrock coring program and the previous surface geophysical surveys, the logs provided a basis for defining the stratigraphic and structural framework of the Study Area. In addition, the selection of well completion depths was strongly influenced by the geophysical and video information.

4. The coring and logging activities revealed that both high-angle (joint) and horizontal (bedding plane) fractures are found throughout the Study Area, at all levels in the investigated strata. The extent of development of these features is quite variable from location to location. In some areas, dissolution of the fractures is extensive such that they can transmit large amounts of water. The strata of the middle and lower Camillus are extremely friable and "rubbleized" within the Study Area. In the Falkirk, high-angle fractures are relatively common, but are not usually enlarged by solutioning. Unlike joints, bedding plane fractures may be continuous across wide areas.

5. The aquifer tests provided useful estimates of in-situ hydraulic conductivity across the Study Area. Measured hydraulic conductivities (K) for various vertical intervals throughout the hydrogeologic unit were high, particularly for a bedrock system. K values in the 10^{-2} to 10^{-4} cm/sec range are typical for tested strata. The highest K values were generally in the lower Camillus and Syracuse wells. The test results were utilized to evaluate the potential and relative permeability of various bedrock strata or intervals, and to identify potential preferential groundwater flow zones and contaminant migration pathways in the bedrock. The data were also considered during the identification of potential remedial technologies and preliminary screening of alternatives performed during the Feasibility Study.

6. The most significant topographic feature of the Study Area is the Mud Creek gorge. This feature is the result of the erosion of approximately 70 feet of strata by a formerly more vigorous Mud Creek. This creek has since become connected with subsurface conduits, and rarely flows at the ground surface. The location and orientation of the gorge appear to be structurally controlled. Groundwater levels are sufficiently high for a few weeks in the spring of each year such that Mud Creek flows above ground through the Study Area to its confluence with Oatka Creek. Several ponds form on the ground surface and, as the water table drops, the stretch of Mud Creek north of the LeRoy Airport drains into the subsurface and recharges the groundwater system. Although the Mud Creek channel is not eroded quite so dramatically to the east and southeast of the Site, the underlying fractured bedrock strata exert a considerable influence on the local groundwater system.

7. Several hydrological features (sinking streams, limited runoff, voluminous springs) reflect the underdrained nature of the exposed bedrock surface. The investigation confirmed that secondary porosity is well-developed in the shallow bedrock, thereby permitting rapid infiltration of precipitation and runoff, and access to significant fractures at depth.

8. A conceptual model of the hydrogeologic system within the Study Area was developed. The model consists of a hydrogeologic unit comprised of approximately 200 feet of bedrock strata. The conceptual model does not include the typically thin and dry overburden materials or the bedrock below the maximum limit of investigated strata (upper Syracuse Formation). Abundant water level data lead to the conclusion that the entire investigated thickness of bedrock beneath the Study Area behaves, in general, as a single hydrogeologic unit.

9. Minor to moderate vertical hydraulic gradients characterize the 18 monitoring well locations. Gradients are generally directed downward from the Onondaga, and upward from the lower Camillus. The Falkirk and/or upper Camillus usually have the lowest potentiometric heads.

10. On a regional scale, groundwater flow within the hydrogeologic system has been determined to be generally toward discharge areas to the east. Spring Creek appears to serve as a discharge area for a substantial portion of the groundwater beneath the Study Area. The creek is sourced by multiple, large-volume springs that are projected to occur at, or near, the top of the Bertie Formation. The thick, extensive deltaic deposits located to the east of

Spring Creek, and south of the Village of Caledonia, may also receive substantial subsurface "discharge" from the hydrogeologic system. Groundwater discharge also occurs in the Mud Creek gorge, via the exposed Bertie and Camillus Formations. Discharge to the gorge is greatest during the spring months, when groundwater levels are high.

11. Precipitation results in relatively uniformly distributed recharge to the hydrogeologic system. More concentrated recharge may occur along a belt that roughly parallels Route 5, and possibly along segments of Oatka Creek to the west of the Study Area. Four streams, including Mud Creek, sink into the subsurface within the postulated recharge belt along Route 5. Well cluster DC-12, located in this belt, consistently features downward hydraulic gradients. This supports the concept of recharge in the area.

12. Groundwater levels rise rapidly, and by large amounts, during precipitation events. This phenomenon reflects the generally low water-storage capacity of the fractured rock underlying the Study Area (with the exception of the Camillus). Some of the intermediate-depth wells at locations west of Church Road responded sooner to a precipitation event than shallower wells. This suggests that recharge at these locations occurs by the lateral influx of a groundwater mass, rather than by the infiltration of rainfall. This mechanism may be operative in other parts of the Study Area as well.

13. Groundwater levels also vary considerably throughout the year. Seasonal water level fluctuations of nearly 60 feet have been noted at cluster DC-7R, along Church Road. With the exception of the wells at clusters DC-13 and DC-14, groundwater elevations exhibit larger seasonal fluctuations in wells located to the east of Mud Creek than in wells located to the west of the creek. The relative stability of water levels in wells DC-13 and DC-14 reflects the fairly constant seasonal discharge of Spring Creek, located 1000 feet or less to the east.

14. During low-water conditions, such as in August, groundwater flow throughout the investigated section is generally toward the east-southeast, with minor flow toward the Mud Creek gorge (northeast). During high-water conditions, such as in March, groundwater in the Onondaga and Falkirk beneath the spill site flows strongly toward the Mud Creek gorge. Although it was also evident in the deeper strata, the flow toward the gorge is less pronounced than in the shallower strata.

15. During low-water conditions, the potentiometric surface slopes steeply to the east in the area between Mud Creek and Church Road. The gradient is considerably less during high-water conditions. The slope reflects the loss of aquifer pressure due to bedrock conditions in the area. These conditions may include the presence of a fracture zone that may be the southwestward extension of a structure underlying the Mud Creek gorge.

16. A comprehensive environmental monitoring program was conducted throughout the Study Area for a period of one year (July 1993 to July 1994). The program consisted of surface water and groundwater level monitoring and the collection of samples from environmental

sampling locations (springs, surface water bodies and sediment deposits), domestic drinking water supplies (groundwater), and newly installed monitoring wells (groundwater). The results provided a thorough year-long review of surface water and groundwater levels and quality at pertinent locations throughout the Study Area.

17. The nature and identity of the spill-related contaminants (TCE and cyanide) resulted in a limited number of contaminants-of-concern, and the development of a sampling and analytical program that focused on volatile organic compounds [TCE and its principle degradation products cis- and trans-1,2 dichloroethene, and monochloroethene (vinyl chloride)] and cyanide.

18. The analytical results indicate that approximately 15,000 cubic yards of overburden/fill materials at the Site are contaminated with TCE, which is leached by infiltrating water from these materials, and transported downward into the bedrock.

19. Although our field screening program failed to directly detect the presence of NAPL as the wells were being drilled, the very high TCE levels detected in subsequent sampling strongly imply the presence of NAPL near wells DC-1A, DC-5A, and DC-15A. This pattern suggests that substantial NAPL spreading has occurred in the vadose zone above the normal position of the water table. Rising groundwater during the spring months apparently comes into contact with this residual NAPL, and creates a highly contaminated "slug" of groundwater.

20. The area underlain by possible NAPL covers roughly seven to 10 acres and may extend to depths of 65 feet. NAPL migration has probably ceased by this time, 24 years after the spill. The slowly dissolving NAPL acts as a continuing source of groundwater contamination, and is responsible for the presence of the extensive, dissolved-phase TCE plume in the Study Area.

21. Contaminated groundwater is apparently drawn toward the water supply well at Dolomite Products. Contamination detected in Dolomite's quarry discharge water indicates that contaminated groundwater flows, or is drawn, toward the southwest in the (quarried) lower members of the Onondaga Formation.

22. TCE concentrations in springs and surface water in the Mud Creek gorge generally decrease with increasing stratigraphic depth and distance from the spill. Maximum TCE concentrations as high as 630 μg/l have been detected in the springs, which are projected to be in the Bertie and Camillus Formations.

23. Sediment data from the gorge pond located in the Mud Creek drainageway and the pond located north of the Genesee Country Inn on Spring Creek indicated that the sediments in these ponds have not been significantly impacted by spill-related contaminants.

24. Cyanide has been detected on a sporadic basis in only a few monitoring and domestic wells, and at one spring in the Mud Creek gorge. Concentrations have generally been below the applicable and relevant standard.

25. The TCE plume is rather constricted in the vicinity of Church Road. The north-south extent of the plume appears to be less than 750 feet. This implies that groundwater locally flows through either high-angle fractures, or bedding plane channels. TCE concentrations often exceed 1,000 μg/l in domestic well G-9, located on Church Road. Groundwater in the Onondaga Formation appears to be clean, and contamination is present from the Bois Blanc into the middle Camillus Formation. The plume is between 75 and 100 feet thick in the area of Church Road.

26. The plume becomes considerably broader to the east of Church Road, up to perhaps one mile in the north-south direction. TCE concentrations generally drop to the 50 μg/l range or less at well clusters, and at many contaminated domestic wells east of Church Road. Contaminated groundwater flows through the Falkirk member and the upper Camillus Formation. The plume is no more than 70 feet thick in this area.

27. Parts of the eastern end of the plume along Spring Street are characterized by relatively high levels of contamination. TCE concentrations in the 25 to 100 μg/l range are typical in domestic wells (and one spring) located within roughly 1000 feet of the Monroe-Livingston County line. Contamination is present in the Falkirk, Camillus, and upper Syracuse strata in this area. The maximum depth of contamination is unknown at the east end of the plume.

28. A competent, relatively impermeable layer of rock which defines the lower limit of the plume does not appear to be present. The apparent plume bottom in the upper Camillus (except along Spring Street) may be controlled hydrodynamically by the upward hydraulic gradient that generally prevails year-round in the lower Camillus.

29. The estimated TCE volume in the entire dissolved phase plume (TCE>5 μg/l) is approximately 200 gallons.

30. A volume exchange time (VET) calculation indicates that the natural replacement of a pore volume of groundwater would be between 18 and 131 years. This suggests an idealized approximate time to naturally remove contaminated groundwater from fractures and pores, respectively, once the contaminant source area has either been remediated or hydraulically isolated.

31. Based on the exposure pathways presented in the quantitative HHE (Volume II of the RI report), there are two current exposure scenarios that may pose a potential long-term health concern. These exposure pathways are:

    - direct contact with Site soils by a nearby rural resident trespassing on the Site; and
    - ingestion and household use of groundwater by nearby rural residents.

Direct contact with Site soils by a nearby rural resident trespassing on the Site may pose a carcinogenic health risk. The risk of developing cancer is primarily due to the presence of the carcinogenic polycyclic aromatic hydrocarbons (PAHs) detected on the Site (i.e., chrysene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene and benzo(a)pyrene. PAHs are commonly associated with railroad construction/use materials; their presence is not related to the derailment/spill.

The noncarcinogenic hazards and excess cancer risks to nearby rural residents due to ingestion and household use of groundwater are primarily due to the presence of trichloroethene.

32. There are five future use scenarios that may pose health concerns:

- direct contact with Site soils by future Site residents;
- direct contact with Site soils and inhalation of volatiles/fugitive dust aerosols by future Site construction workers;
- ingestion and household use of groundwater by future residents;
- direct contact with groundwater by future residents while in a wading pool, and
- inhalation of indoor air by a future Site resident.

Under these theoretical future soil exposure scenarios, the noncarcinogenic risks from the direct contact with soil SSCs (and inhalation of volatiles and fugitive dust aerosols by a future construction worker) are primarily due to the presence of trichloroethene. Excess cancer risks associated with future soil exposures by Site residents and construction workers are primarily due to the presence of trichloroethene and the carcinogenic PAHs, with the one detection of Aroclor-1260 in surface soil also contributing to the cancer risk posed to future Site residents. The PAH compounds and Aroclor-1260 are not related to the spill.

The noncarcinogenic health hazards associated with ingestion and household use of groundwater by a future resident are due to trichloroethene, carbon tetrachloride, tetrachloroethene and 1,2-dichloroethene. Trichloroethene and carbon tetrachloride may also contribute to the noncarcinogenic hazards associated with the hypothetical exposure of future residents to groundwater due to its use for filling a wading pool. The cancer risks associated with ingestion and use (household and wading pool) of groundwater by future Study Area residents are due to the presence of trichloroethene, tetrachloroethene and carbon tetrachloride.

Because indoor air samples were not collected from homes during the RI, screening methods were used to evaluate potential inhalation exposures of future residents to volatile SSCs that may migrate into indoor air from soil and groundwater emissions. These results indicate that carcinogenic risks are primarily due to trichloroethene and tetrachloroethene; lesser risks are related to the presence of carbon tetrachloride.

33. Based on the current understanding of the Site history, the only SSCs detected in environmental media at the Site which might be related to the train derailment are trichloroethene and its breakdown products, and cyanide. The remaining SSCs, especially the PAHs and inorganics, are often associated with railroad construction/use materials. The potential source(s) of carbon tetrachloride and tetrachloroethene has not been determined.

34. The Fish and Wildlife Impact Analysis (FWIA) Step I Site Description and associated tasks revealed that the habitats that could potentially have been impacted by spill-related contaminants consisted of the Mud Creek drainageway, including the gorge pond, Oatka Creek, and the Spring Creek drainageway, including the springs located along Spring Creek and the Caledonia State Fish Hatchery.

35. The Criteria-Specific Analysis of the FWIA consisted of an evaluation of the available environmental analytical results and comparison with applicable surface water and sediment standards. A review of the data indicated that TCE was the predominant compound detected in environmental media. Vinyl chloride was not detected in any of the environmental samples.

36. A comparison of the spring and surface water analytical results from the Mud Creek and Spring Creek drainageways to published and derived Criteria-Specific Standards, indicated that the reported TCE concentrations are below the calculated guidance value for the protection of aquatic life (1,217 μg/l) and that spill-related contaminants have not impacted water quality with respect to aquatic life. Data from the gorge pond located in the Mud Creek drainageway and from Spring Creek indicate that water quality in Oatka Creek would not be adversely impacted by spill-related contaminants via discharge of water from these two areas.

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