REMEDIAL INVESTIGATION
FOR THE CARBORUNDUM FACILITY
SANBORN, NEW YORK

June 1990

Prepared for:

THE CARBORUNDUM COMPANY
2050 Cory Road
Sanborn, New York 14132

ecology and environment, inc.
BUFFALO CORPORATE CENTER
368 PLEASANTVIEW DRIVE, LANCASTER, NEW YORK 14086, TEL. 716/684-8060
International Specialists in the Environment

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EXECUTIVE SUMMARY

This final Remedial Investigation Report (RI) has been completed for BP America Inc. to address chlorinated organics primarily in the groundwater on and in the vicinity of its Carborundum Company facility in the Town of Wheatfield, New York. The RI has been performed at the request of the New York State Department of Environmental Conservation (NYSDEC) under the Order on Consent (Site Number 932102) that was implemented on February 21, 1989. The RI is designed to assess the source and extent of chlorinated organics in soils and groundwater, to determine the risk of these compounds to potential receptors, and to provide a Feasibility Study (FS) work plan.

The RI provides a comprehensive review and interpretation of data gathered at the Carborundum facility and in its vicinity from 1984 through May 1990. These data result primarily from three major field investigations that were performed in 1984, 1986, and 1988-89 and a Phase II Field Investigation which was performed in 1989-90.

The significant results of the RI and the risk assessment are presented in the following discussion.

Trichloroethene (TCE) was used at the Carborundum facility from 1963 to 1983. During this period, TCE was introduced to the overburden soils primarily in four areas which surround the manufacturing buildings. Knowledge that a problem existed at the facility was first discovered in 1983 when elevated levels of TCE were found in the facility's production well, P-2, during a routine NYSDEC inspection.

Presently TCE and its primary degradants 1,2-dichlorethene (1,2-DCE) and vinyl chloride (VC) are the most common chlorinated organics contained in the aquifer in the area of the facility. These chemicals are restricted primarily to the shallow portion (upper 20 feet) of the Lockport Dolomite bedrock aquifer. In most areas of the facility, TCE and its degradants are not found in deeper portions of the aquifer; only one deeper well contains levels of these compounds that warrant concern.

Chlorinated organics in overburden soils at the facility are primarily restricted to the previously noted source areas. Groundwater rises into the overburden during periods of groundwater recharge, primarily in late winter and spring. Off site to the southwest, groundwater is restricted to the bedrock throughout the year. While the overburden on site is periodically saturated, its hydraulic conductivity is so low that it does not transmit significant amounts of groundwater laterally and is classified as an aquitard.

Groundwater in the bedrock moves away from the facility to the south, southeast, and southwest. Plume movement also occurs in the shallow bedrock aquifer in all of these directions; however, the primary migration of the plume is to the southwest. The migration of the plume is controlled by the high hydraulic gradient to the southwest. Chlorinated organics, principally 1,2-DCE and VC, have been found in monitoring wells to the southwest at levels which exceed drinking water standards. Sampling data from domestic wells further downgradient beyond the current monitoring well network, as well as rapid declines in concentration in that direction, suggest that the plume falls to non-detectable levels prior to reaching any downgradient receptors.

Pumping tests performed in on-site recovery wells, P-2 and P-3, indicate that a sufficient capture area can be attained by pumping these two wells to prevent further plume migration. Preliminary interpretation of degradation patterns off site suggests that an on-site treatment program which utilizes pumping and treatment of the groundwater and remediation of overburden source areas will be effective at reducing chlorinated organic levels to drinking water standards in the off-site plume.

Four potential exposure routes were considered in assessing the risks posed by chlorinated organics at the Carborundum site. These were:

- Inhalation by facility workers of vapors emanating from the ground;

- Inhalation by residents of the adjacent DoD housing area of vapors emanating from the ground;
- Inhalation of vapors and ingestion of contaminated surface soils by facility workers in the area of the State Pollution Discharge Elimination System ditch; and
- Inhalation and ingestion of chlorinated organics from groundwater as a result of using the groundwater for domestic supply purposes.

The first three scenarios could actually occur under existing conditions while the fourth scenario is presently only hypothetical since groundwater is not presently used for domestic supply purposes in the area where chlorinated organics have been found in the groundwater.

The estimated risks associated with the first three exposure scenarios were several orders of magnitude less than the benchmark levels used to distinguish risks of potential concern from those that would generally be considered insignificant and acceptable. Therefore, potential exposures to chlorinated organics via airborne pathways that could actually occur under existing conditions do not appear to pose any significant risks to human health.

Groundwater in the immediate vicinity of the Carborundum facility where chlorinated organics have been found would pose a health risk if it were to be used for domestic supply purposes such as drinking, showering or bathing over extended periods. However, groundwater in the affected area is not presently used for domestic supply purposes, as there are no homes with residential wells or basements in the affected area. Consequently, the estimated risks associated with groundwater usage are not applicable to any residents around the site.

1. INTRODUCTION

This Remedial Investigation (RI) has been completed for BP America Inc. (BP) for its Carborundum Company (Carborundum) manufacturing facility located at 2050 Cory Road in the Town of Wheatfield, New York. The RI is being performed at the request of the New York State Department of Environmental Conservation (NYSDEC) under the Order on Consent (Site Number 932102) which was implemented on February 21, 1989. Ecology and Environment, Inc. (E & E), under contract to BP, was requested to perform the RI and the Feasibility Study (FS). The FS will be a separate report and will be submitted 60 days following NYSDEC's approval of the final RI report.

The purpose of the RI at the Carborundum facility was to:

- Assess the source and extent of chlorinated organics contamination in the soil and groundwater;
- Determine the risk to human health and the environment that the chlorinated organic contamination poses; and
- Prepare an FS work plan as part of the RI as requested in the Order on Consent.

This RI has been developed using the guidelines of the Interim Final March 1989 United States Environmental Protection Agency (EPA) document, Guidelines for Conducting Remedial Investigations and Feasibility Studies Under CERCLA.

A Phase II investigation was recommended at the completion of the draft RI report to gather additional data primarily regarding the extent of chlorinated organics beyond the facility boundary. Specific elements of the Phase II investigation which have been performed and are summarized in this report include:

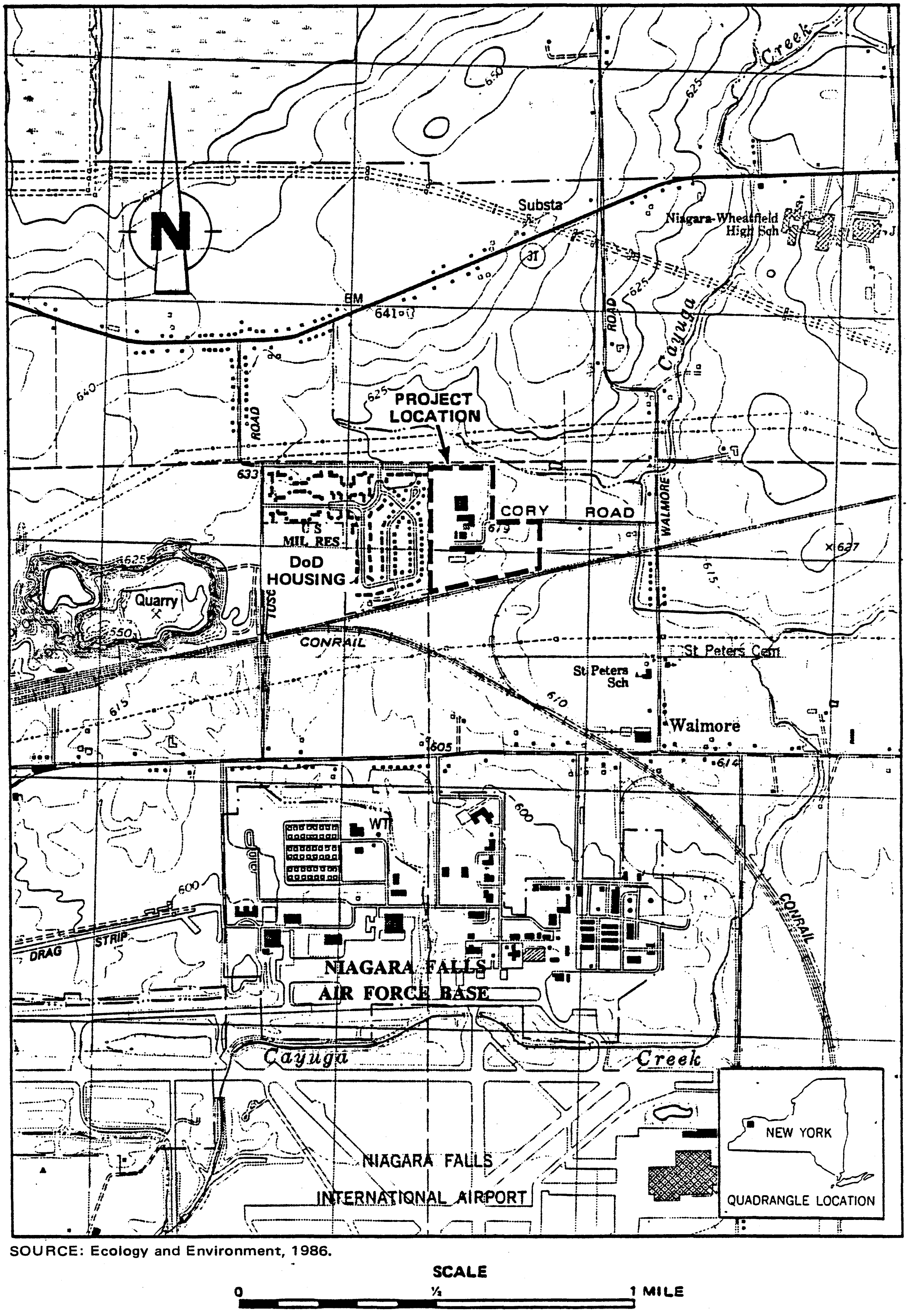
- o Further evaluation of the extent of chlorinated organics in the shallow bedrock by installing four additional monitoring wells--three to the southwest and one to the east of the facility;
- o Additional surface and subsurface soil sampling in the inactive State Pollution Discharge Elimination System (SPDES) outfall to determine if high levels of chlorinated organics exist in the shallow subsurface in the outfall;
- o A soil gas survey performed at the Department of Defense (DoD) housing facility, located at the western boundary of the plant, to verify that the residents of the housing facility are not impacted by the groundwater plume; and
- o Perform an Interim Remedial Measure (IRM) to tanks at the facility (some were known to serve as sources for chlorinated organics).

The original draft RI report, which was completed in August 1989, has been adapted and edited to the final RI report. The Risk Assessment was also changed in the same manner. Changes which have been made to the draft RI report appear throughout the text. Most changes and additions appear in Section 3, Investigation Methodology; Section 4, Nature and Extent of Contamination; and Section 5, Risk Assessment. Section 7, Conclusions and Recommendations, has been rewritten to reflect Phase II RI results and recommendations regarding further studies and site-wide remediation.

1.1 SITE DESCRIPTION

The Carborundum facility is located in a rural area in the Town of Wheatfield, Niagara County, New York (see Figure 1-1). The facility property is approximately 40 acres in size and lies on the north side of the New York Central railroad easement. The majority of land immediately adjacent to the facility is used for agricultural purposes. DoD military housing borders the facility along its western side (see Figure 1-2). Numerous other private residences are within a 0.75-mile radius of the facility. In addition, the Niagara Falls Air Force Base is located about 0.5 mile south of the facility.

Surface topography in the facility area generally slopes southward at a rate of about 5 feet per mile toward the Niagara River. Surface



SOURCE: Ecology and Environment, 1986.

Figure 1–1 CARBORUNDUM FACILITY LOCATION MAP

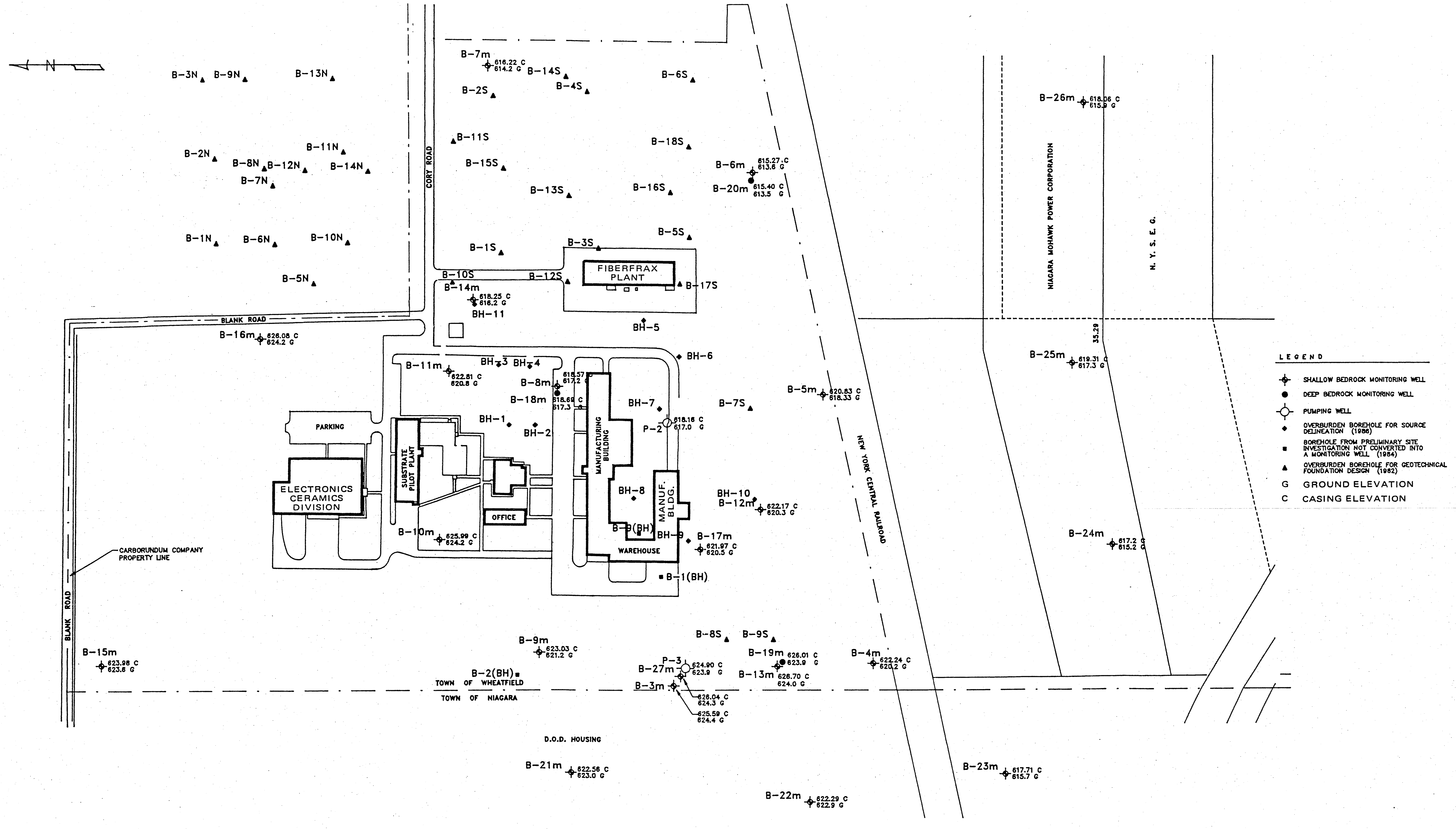


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Figure 1–2 FACILITY LAYOUT MAP

SCALE	DATE ISSUED	C.A.D. FILE NO.	DRAWING NO.	REV.
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water from the active areas of the facility discharges into the plant's sewer system which discharges to the Niagara County Sewer District 1 Sewage Treatment Plant. Cayuga Creek is located about 0.25 mile east of the facility and flows southward for about 4.5 miles until it discharges into the Niagara River in the City of Niagara Falls. Prior to this investigation, the SPDES outfall, which is presently inactive, carried surface runoff and non-contact cooling waters from the facility into Cayuga Creek.

Site geology consists of 7 to 20 feet of unconsolidated glacial lake sediments and till which is underlain by the Lockport Dolomite. Shallow horizontal and vertical fractures in the weathered uppermost section of the Lockport Dolomite comprise the primary aquifer beneath the facility. This weathered zone ranges in thickness from about 10 to 20 feet and appears to be the predominant route for migration within and off the site.

1.2 SITE HISTORY AND PREVIOUS INVESTIGATIONS

Operations at the Carborundum facility commenced in 1963. Trichloroethene (TCE), the principal chlorinated organic found in the groundwater, was used from 1963 until 1983 as a degreasing solvent in the manufacture of carbon and graphite cloth. Other chlorinated organics used during this period included 1,1,1-trichloroethane (TCA) and carbon tetrachloride. TCA was used on a trial basis as a degreasing solvent in the cloth manufacturing process and as a source of chlorine in the purification of graphite. Carbon tetrachloride was also used as a source of chlorine in the purification process and is no longer in use. TCA is still used as a purifying agent. Methylene chloride (MC) is currently used (beginning in June 1988) as a solvent in the filter manufacturing process.

Concern that chlorinated organics in the overburden and groundwater might pose a problem at the Carborundum facility was first raised in 1983 when TCE was found in the facility's SPDES outfall from samples collected during a NYSDEC inspection and in groundwater samples collected from production well P-2. Four phases of investigation, involving soil borings, well installation, groundwater sampling, a soil gas survey, pumping tests, private well and sump sampling, and seismic and resistivity geophysical surveys, have been implemented since TCE was first found in the SPDES outfall. Groundwater samples were first collected in August 1984 during the first field investigation. Since March 1985, groundwater samples have been collected on a quarterly basis. The chlorinated organics that have been found include TCE, TCA, trans-1,2-dichloroethene (trans-1,2-DCE), and cis-1,2-dichloroethene (cis-1,2-DCE), 1,1-dichloroethane (1,1-DCA), vinyl chloride (VC), carbon tetrachloride, MC, chloroform, 1,1-dichloroethene (1,1-DCE), and tetrachloroethene (PCE).

Six monitoring wells (B-3M through B-8M) were drilled and installed at the facility during the first phase of work in 1984 (see Figure 1-2). Each well was installed into approximately the top 5 feet of the weathered section of the Lockport Dolomite. The highest TCE concentration encountered during this first phase of work was 98,000 parts per billion (ppb) from groundwater in well B-8M. Other confirmed high concentrations encountered included total-1,2-DCE (110,000 ppb) and VC (1,300 ppb) from well B-3M; total-1,2-DCE (4,500 ppb); and TCE (670 ppb) from groundwater in well B-4M and total-1,2-DCE (14,000 ppb) from well B-8. During this same period, groundwater data from the other wells yielded comparatively low concentrations of chlorinated organics.

The second phase of work began in March 1986 and continued through 1987. The tasks that yielded significant information during the second phase of work were a soil gas survey, the installation of six additional monitoring wells, a seismic refraction survey, residential well sampling, quarry seep sampling, and the completion of a 24-hour pumping test.

The soil gas survey demonstrated four areas of high concentrations (ranging from 10 to 3,500 micrograms per liter [µg/L]) of TCE in shallow soil gas in the area of the manufacturing building. These data, in combination with data from groundwater monitoring, resulted in a second phase of monitoring well installation which included six additional shallow bedrock monitoring wells (B-9M through B-14M) installed on the site during November and December 1986.

A 24-hour pumping test, which utilized production well No. 2 as the pumping well, was also completed in December 1986. The pumping test indicated that groundwater over much of the site could be captured and treated by pumping production well No. 2 (P-2). However, it was also noted that an additional pumping well would be necessary to capture the groundwater plume at the western edge of the site, at and around well B-3M. Groundwater concentrations of VC, total-1,2-DCE, and TCE measured in the parts per million (ppm) range in this well.

Groundwater from 22 private residential wells was sampled by the Niagara County Department of Health in 1985 and 1988. (For continuity, the May 1988 residential well sampling is included in the second phase of work because a more extensive residential well sampling event was performed in December 1988 during the third phase of work.) One well, which was 5,000 feet upgradient of the facility, contained a low level of TCE (4.6 ppb). Since the well was so far upgradient, its contamination is not considered to be attributable to the facility. Two other wells yielded low concentrations of chloroform (2.0 to 11 ppb) and one well showed MC (5.1 ppb). None of these chlorinated organics were derived from the Carborundum facility. This conclusion is supported by the fact that two of the locations are upgradient and none of the wells contained the expected chemicals of the downgradient chlorinated organics plume, 1,2-DCE and VC. No other well sampled contained chlorinated organics.

The third phase of work, which was completed in 1988 and 1989, was designed to further define the extent of chlorinated organics in the groundwater and to investigate potential aspects of the site that would affect remedial design. Tasks performed in the third phase of the study included the installation of 10 shallow bedrock monitoring wells and three deep bedrock monitoring wells; the performance of residential well and sump sampling within a 0.75-mile radius of the site; the installation and testing of a second recovery well at the western boundary of the site adjacent to B-3M; sediment and surface water sampling in the inactive SPDES outfall and in Cayuga Creek; the sampling for the potential presence of Dense Non-Aqueous Phase Liquids (DNAPL) in the two monitoring wells (B-8M and B-17M) with the highest levels of chlorinated organics; a man-made passageway investigation of the sewer trench on Cory Road; the conceptual development of two Internal Remedial Measures (IRMs) for septic tank closure and application of vacuum extraction technology in a source area as a pilot program.

The Phase II RI, which was completed in the last quarter of 1989 and the first half of 1990 and constituted the fourth phase of field investigation, included the installation of four additional shallow bedrock monitoring wells to the southwest and east of the facility; the performance of a soil gas survey at the DoD housing facility to the west of facility boundary; the completion of shallow subsurface soil sampling in the SPDES outfall; the completion of an IRM for septic tank closure; and the preparation of a vacuum extraction treatability study in a source area.

The RI focuses on the integration of data from all investigation phases so that a coherent interpretation of the type and extent of chlorinated organics in the soil and groundwater, and their associated risks, are defined. In addition, the RI will recommend additional studies to be performed at the facility.

2. REGIONAL CHARACTERISTICS OF THE STUDY AREA

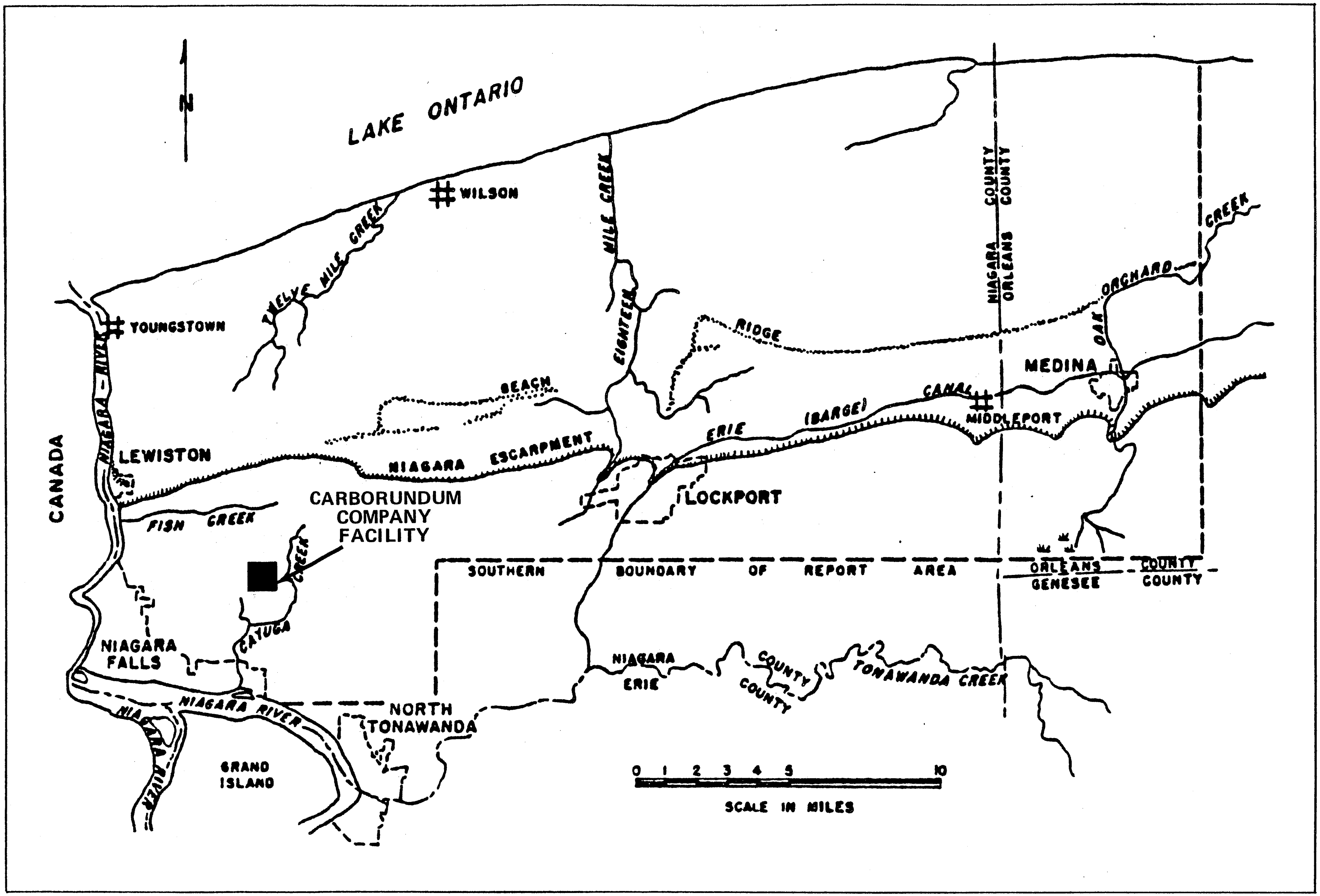
2.1 INTRODUCTION

This section summarizes the physical and climatic characteristics of the site from a regional perspective (the Niagara Falls area) in order to provide a background for the field investigations. Site-specific details of the geology and hydrogeology are presented in Section 4.

2.2 SURFACE TOPOGRAPHY AND DRAINAGE

The Carborundum facility is located in the Niagara Falls area in the northwestern corner of New York. It lies in a region of low relief in the glacial lake plain east of the Niagara River and south of Lake Ontario. The principal topographic features of this region are the gorge of the Niagara River and the east-west trending Niagara escarpment (see Figure 2-1). At the river, the escarpment is a 200-foot high cliff that gradually diminishes to the east into a broad, gentle incline. The plain north of the escarpment slopes almost imperceptibly toward Lake Ontario.

The Lake Tonawanda Plain, which lies south of the Niagara escarpment, is also a fairly flat-lying area. A topographic low trends east-west through the plain and is drained along its axis by Tonawanda Creek. The Carborundum facility in the Town of Wheatfield lies north of Tonawanda Creek, south of the Niagara escarpment, and west of Cayuga Creek (see Figure 2-1). Cayuga Creek was a surface drainage route for the Carborundum facility via the currently inactive SPDES outfall. Cayuga Creek drains into the upper Niagara River which eventually discharges via the Niagara Gorge into Lake Ontario.



SOURCE: Adapted from Johnson 1964.

Figure 2–1 PHYSICAL FEATURES OF THE NIAGARA FALLS AREA

2.3 REGIONAL GEOLOGY

The surface of the Niagara Falls area is covered by a thin layer of unconsolidated deposits laid down during the closing phases of the great ice age, or Pleistocene Epoch. In the wake of the receding glaciers, terminal moraines, shallow lakes, and small streams were formed. This resulted in the deposition of overburden material composed of glacial till, lake clay, silt, and fine sand, and localized stream-deposited sands and gravels.

The bedrock of the Niagara Falls area consists of nearly flat-lying Paleozoic sedimentary rocks. These sediments were deposited during the Middle Silurian, a period characterized by extensive shallow seas. During the Late Silurian, restricted seas caused the precipitation of salt, gypsum, and anhydrite deposits. At the close of the Silurian Period, the sea withdrew from Western New York but persisted in the eastern part of the state. The remainder of the Paleozoic Era, as well as the Mesozoic and most of the Cenozoic Eras, have left no geologic record in the Niagara Falls area of Western New York (Buehler and Tesmer 1963).

The Silurian bedrock units beneath the Niagara Falls area are composed of dolomite, shale, limestone, and sandstone (see Figure 2-2). The bedrock dips to the south at approximately 30 feet per mile. The depth to bedrock is on the order of 7 to 20 feet in the vicinity of the Carborundum facility and the first rock unit encountered is the Lockport Dolomite.

The member of the Lockport Dolomite investigated beneath the Carborundum facility is the Oak Orchard. The Oak Orchard comprises over half of the mass of the Lockport formation in Western New York and is on the order of 60 feet thick. Minerals such as anhydrite, sphalerite, fluorite, pale yellow calcite, and galena are often found recrystallized in the vugs and fractures within the Lockport. Hemispherical masses called stromatolites and disorganized fossiliferous masses called biostromes have been found in several areas within the Oak Orchard member, including the quarry immediately west of the study area. These features are generally 4 to 10 feet across (Zenger 1965), but have also been reported to be as large as 50 feet across and 10 to 20 feet thick (Johnson 1964). Their tops are convex upwards and their bases are less

Table 1.--Water-bearing characteristics of unconsolidated deposits and bedrock in the Niagara Falls area

Age			Water-bearing unit	Thickness (feet)	Lithologic description	Yield of wells (gallons per minute)	Water-bearing characteristics
Silurian	Unconsolidated deposits		Sand and gravel	0-70	Fine- to medium-grained sand interbedded with coarse sand and pebbles.	1-200	Highly permeable. Sand and gravel generally occurs in thin deposits in isolated hills and in the "beach ridge." Thinness of the deposits and occurrence as topographic highs prevent development of large supplies. Wells are almost always adequate for domestic use and locally are adequate for small commercial supplies.
			Lake clay, silt and fine sand	0-90	Laminated clay and silt with thin beds of fine sand.	Generally less than 1	Clays and silts have very low permeability and yield little water. Water is found principally in the fine sand. Wells penetrating sand beds are generally adequate for domestic use.
			Glacial till ("Hardpan")	0-20	Mixture of boulders and pebbles in a matrix of sand, silt, and clay.	Generally less than 1	Water occurs principally in thin sand lenses in till and a "washed zone" at the top of bedrock. The washed zone often directly overlies a fractured zone in the bedrock forming a continuous aquifer. Wells penetrating the washed zone are usually adequate for domestic use.
	Bedrock	Lockport Dolomite	Upper part and middle part (Oak Orchard Member)	110	Dark-gray to grayish-brown dolomite, massive to thin bedded, locally containing algal reefs and small masses of gypsum.	Major part of area 2-110 (average 31)	Ground water occurs principally in 4 water-bearing zones parallel to bedding which are much more permeable than the surrounding rock. Vertical joints and small cavities formed by solution of gypsum yield small amounts of water, particularly in the upper 10 to 15 feet of rock. Wells are usually adequate for domestic and small commercial uses.
						Small area adjacent to upper Niagara River 50-2,200 (average 800)	Same as above except that the bedding joints, which comprise the principal water-bearing zones, and the vertical joints are hydraulically connected to the Niagara River. This permits the development of large supplies, much of which infiltrates from the Niagara River. Yields of individual wells vary greatly because of differences in the degree to which bedding joints have been widened by solution and variations in the number and spacing of vertical joints.
			Lower part (Gasport and DeCaw Member)	40	Gray to brown dolomite, locally containing gypsum. Light gray coarse-grained limestone and shaly dolomite at the base.	½-20 (average 7)	Ground water occurs principally in 3 water-bearing zones parallel to bedding. These 3 zones are less permeable than those in the upper and middle Lockport, causing wells to have lower yields. Wells are usually adequate for domestic uses except immediately adjacent to the Niagara escarpment where part of the Lockport is dewatered.
			Clinton and Albion Groups (Rochester, Grimsby, Whirlpool)	200	Light gray limestone grading downward into shale, alternating beds of shale and sandstone, and white sandstone at the base.	½-5 (average 2½)	Ground water occurs principally in bedding joints and vertical joints within the sandstones and limestones. The limestone near the top (Irondequoit) and basal sandstone (Whirlpool) yield most of the water. The Rochester Shale at the top is almost impermeable and acts as a confining bed to the limestones and sandstones below.
Ordovician			Queenston Shale	1,200	Red sandy to clayey shale	7 (In fractured or weathered zone)	Ground water occurs principally in a fractured zone in the top few feet of shale. The remainder of the formation is almost impermeable. Wells not obtaining water from the fractured zone are usually inadequate for domestic use.

SOURCE: Adapted from Johnson 1964.

Figure 2–2 STRATIGRAPHY AND WATER-BEARING CHARACTERISTICS OF THE UNCONSOLIDATED DEPOSITS AND BEDROCK IN THE NIAGARA FALLS AREA convex downward. They are composed of laminated dolomite and contain no internal bedding. Because of their lack of bedding planes, they may be less permeable than the surrounding bedrock.

2.4 REGIONAL HYDROGEOLOGY

Published regional groundwater flow maps for groundwater movement in the upper Lockport Dolomite do not extend as far east as the Carborundum facility. However, extrapolation of the potentiometric surface contours shown in Figure 2-3 suggests groundwater passing through the shallow bedrock beneath the Carborundum facility generally flows to the south toward the Niagara River.

Groundwater in the Niagara Falls area occurs in both the unconsolidated deposits and the bedrock. However, the majority of the overburden is composed of lake silt and clay deposits which are not transmissive enough to yield adequate water for domestic or small agricultural needs (see Figure 2-2 for a summary of the water-bearing characteristics of these sediments). In general, the glacial till deposits within the overburden also do not produce much water. In some locations within the Niagara Falls area the sand and gravel deposits within the overburden do produce enough water to satisfy domestic and small farm demands. However, these sand and gravel deposits are very discontinuous and consequently readily dewater when pumped heavily.

Groundwater within the Lockport Dolomite is the primary aquifer in the Niagara Falls area. Groundwater occurs within the bedrock in secondary openings in the form of fractures due to tectonic stresses, isostatic rebound, and near-surface weathering, and as cavities formed by solution of minerals. Vertical fractures predominately occur in the upper 10 to 20 feet of bedrock. A conjugate northeast-southwest (N 65°E and northwest-southeast (N 30°W) fracture system has been reported in this area (Yaeger and Kappel 1987).

The primary conduits of groundwater flowing through the bedrock are fractures parallel to bedding. The highest flow rates are obtained in these fractures that have been further widened by secondary solution of the rock. These fractures may pinch out laterally and be replaced by other fractures in a complex network. In general, the upper 10 to 20 feet of the Lockport bedrock has more interconnected fractures than the

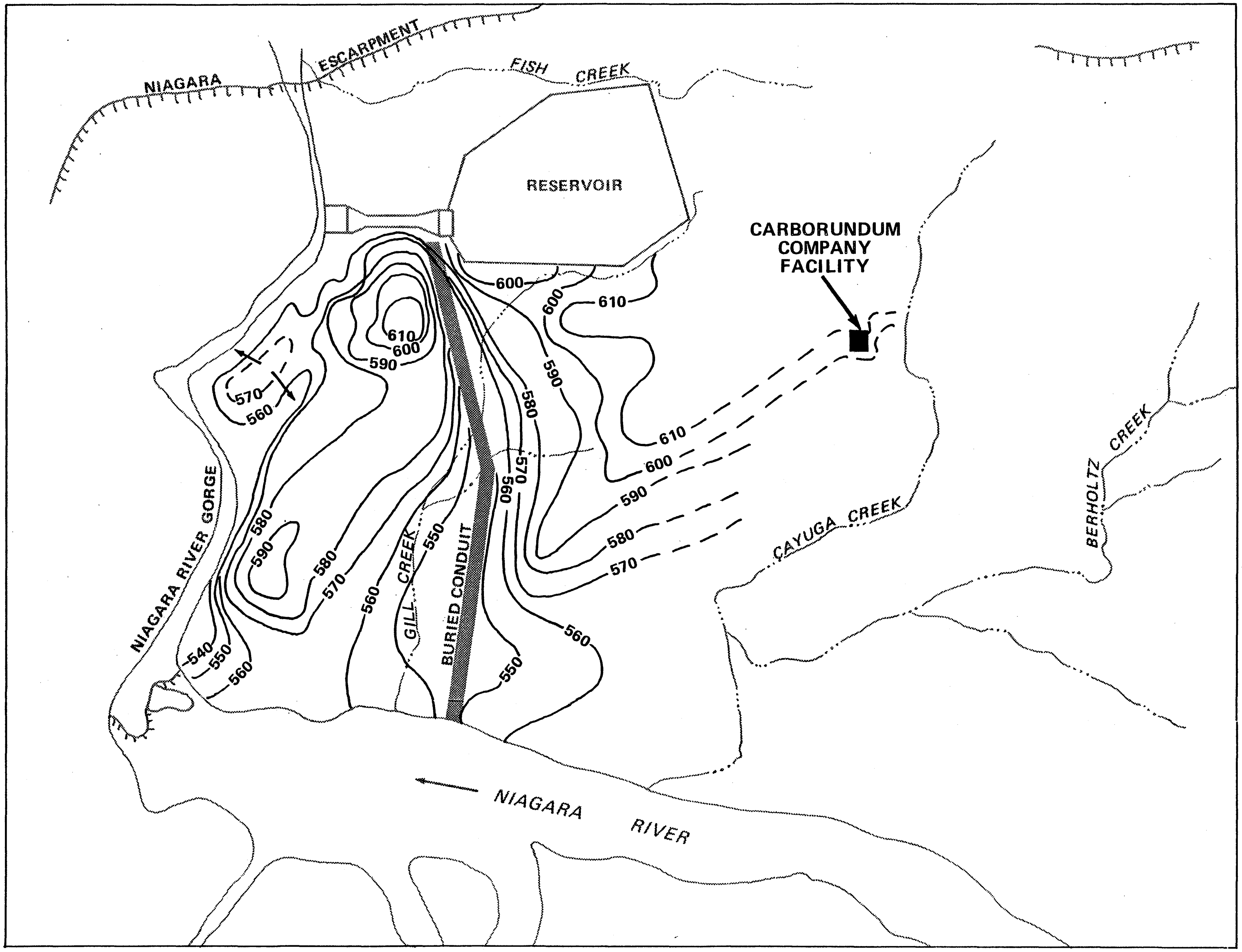


Figure 2–3 REGIONAL GROUNDWATER FLOW IN THE SHALLOW LOCKPORT DOLOMITE EXTRAPOLATED TO THE CARBORUNDUM FACILITY

deeper, thickly bedded intervals and, consequently, is more transmissive.

A thorough description of the fracture system within the bedrock would provide the most comprehensive evaluation of the hydrology of the Niagara Falls area. However, the fractured bedrock of the Lockport is very complex, particularly when focusing on small-scale detail. Bedrock cores, two pumping tests, and a seismic refraction survey from the Carborundum facility provide some of the site-specific detail of fracture interconnectivity. These are described in Section 4.

Average relative estimates of the hydraulic properties of the Niagara Falls aquifers were reported by Johnson 1964. Based on isolated measurements at a limited number of locations, the silts and clays in the overburden were calculated to have a hydraulic conductivity on the order of 0.04 gallon per day per square foot (gpd/ft^2). The hydraulic conductivity of the glacial tills was estimated as less than or equal to 23 gpd/ft^2. The majority of the bedrock aquifer wells produce 1 to 110 gallons per minute (gpm) except for some exceptionally high-yielding wells close to the Niagara River. Regional hydraulic conductivities in the bedrock were reported to range from 8 to 500 gpd/ft^2. The Carborundum facility lies in an area of higher than average hydraulic conductivity where well yields as high as 370 gpm have been obtained and the hydraulic conductivities are on the order of 1,000 gpd/ft^2.

2.5 REGIONAL CLIMATE

Climate in the Niagara Falls area can be characterized as a humid, changeable, continental type, modified considerably by the Great Lakes. Both Lake Erie and Lake Ontario have a direct effect on the area's climate as the prevailing westerly winds crossing these waters moderate winter cold and summer heat.

Winters are long and rather cloudy in this area. Snowfall averages 50 to 60 inches, about 40 inches of which can be expected from general or synoptic storms; the remainder are due to the "lake effect" phenomenon. These lake effect snows, caused by cold air crossing the warmer Lake Erie waters, can affect Niagara County from time to time, but usually remain to the south of the area in Erie County. Only rarely does Lake Ontario induce such activity here. Average daily temperatures fall below freezing from mid-December through mid-March, but thaws occur frequently. Subzero temperatures are quite rare, averaging three occurrences per winter. The ground is snow covered about 60 days in an average year, but periods of bare ground are not unusual even in mid-winter. Ground frost reaches a maximum depth of 3 feet.

The least precipitation frequently occurs in the months of April and May in Western New York. (The high precipitation in the late spring and early summer of 1989 was anomalous.) Typically, groundwater levels remain at some of their highest levels in March because of snowmelt and begin to drop in mid-April and May. The season's last frost usually occurs in late April near the lakeshore and early May inland. Sunshine increases noticeably in spring as the cooler lakes become a stabilizing influence on the area's climate.

Summer begins rather abruptly in mid-June. The prevailing southwest winds off Lake Erie keep temperatures from rising over 90° during all but the most intense heat waves. June and July often have extended dry periods, with soil moisture deficits usually evident by late June. Rainfall increases somewhat in August.

Autumns are dry and mild, at least through October, but cloudiness increases markedly in November and the season's first snowfall can be expected in mid-November.

Niagara County's total precipitation averages 30 to 35 inches and is rather evenly distributed throughout the year. Its frequency and intensity varies from season to season; however, summer rains are intense but of short duration, while winter precipitation is light but frequent.

3. INVESTIGATION METHODOLOGY

3.1 INTRODUCTION

Field investigation activities for environmental purposes have been performed on and adjacent to the Carborundum facility since 1984 after TCE was found in both the groundwater from production well P-2 and in the SPDES outfall which discharged water from the facility to Cayuga Creek. Four phases of fieldwork have been performed at the Carborundum facility to determine the extent of the chlorinated organics on and in the vicinity of the site (see Table 3-1). Each phase of investigation was designed to provide more site-specific information concerning the soil and the groundwater at the site, with particular emphasis on the Lockport Dolomite, which is the primary medium that transports groundwater containing chlorinated organics on and in the vicinity of the facility.

The first phase of work was a preliminary hydrogeologic assessment performed by the Standard Oil Company of Ohio (SOHIO), which was at that time the parent company of Carborundum. Nine soil borings were drilled and sampled during this investigation. Six of these borings were converted to shallow bedrock monitoring wells. During well installation, hydraulic conductivities of the shallow wells were estimated with falling head slug tests and of production well P-2 with double packer constant head tests. Groundwater from these wells was sampled first in August 1984 and thereafter on a quarterly basis beginning in March 1985. A preliminary soil gas survey was also conducted. This investigation was performed during the summer and fall of 1984.

The second phase of field investigation was initiated in 1986. At that time, E & E was retained by Carborundum as its prime consultant to further assess the extent and potential sources of chlorinated organics

Table 3-1

FIELD WORK CHRONOLOGY

	No. of Tasks	Soil Borings	Wells	Soil Gas Survey	Pumping Test	Groundwater Sampling			DNAPL*	Cory Road Sewer Trench	Geophysics	Other
						Quarterly	Residential	Quarry Seep				
1984 Field Investigation	3	9	6 wells in shallow bedrock	Preliminary 26 sample locations		7 wells						
1986 Field Investigation	6		6 wells in shallow bedrock	Expanded 98 sample locations	1 24-hour test at P-2	Expanded 13 wells total	22 residential wells	10 samples			Seismic Refraction VLF, EM-34	
1988-89 Field Investigation	5		10 wells in shallow bedrock 3 wells in deep bedrock 1 extraction well		2 8-hour tests at P-3 1 38-hour test at P-3	Expanded 27 wells total	89 residential wells and sumps		2 samples	1 sample		SPDES Outfall/ Cayuga Creek (7 samples) Employee interview
1989-90 Field Investigation	4		4 wells in shallow bedrock	Expanded 25 sample locations (47 attempts)		Expanded 32 wells total						Tank Closure SPDES Outfall (5 samples)

*Dense Non-Aqueous Phase Liquid

in and around the facility. Tasks performed during this phase of work included:

- The installation of six additional shallow bedrock monitoring wells;
- The completion of a 24-hour pumping test at P-2;
- An expanded program of quarterly groundwater sampling;
- Sampling of surrounding private wells and sampling of seeps from the Medina Sandstone Corporation quarry west of the site;
- An expanded soil gas survey; and
- The completion of three geophysical surveys, including a surface seismic refraction survey, an electromagnetic survey (EM34), and a very low frequency (VLF) survey (EM16).

The work conducted during the second phase of work verified the existence of source areas in the overburden in the vicinity of the manufacturing building and provided sufficient hydrogeologic information to indicate that groundwater extraction and treatment was a feasible remedial alternative for the Lockport Dolomite aquifer. Groundwater data from the newly installed shallow bedrock monitoring wells indicated that the areal and vertical extent of groundwater contamination needed further definition.

The third phase of work, which was completed in 1988 and 1989, was designed to fill data gaps regarding the extent of chlorinated organics in the groundwater and overburden both on site and off site, and to further assess the proposed groundwater remediation approach. Included in the third phase of work were:

- The completion of eight upgradient and downgradient monitoring wells installed in the upper 10 to 15 feet of bedrock around the north, west, and south perimeter of the facility (B-15M, B-16M, B-21M through B-26M);
- The completion of two monitoring wells installed in the upper 10 to 15 feet of bedrock on the western side of the facility (B-17M and B-27M);
- The installation of three deep on-site monitoring wells at the facility (B-18M, B-19M, B-20M);

- The installation of an additional recovery well (P-3) at the western edge of the facility and the performance of preliminary and full-scale pumping tests at this well;
- An expanded program of residential well sampling and first time sump sampling;
- An expanded program of quarterly groundwater sampling to include all newly installed monitoring wells and the performance of DNAPL sampling;
- The performance of surface water and sediment sampling in the inactive SPDES outfall and in Cayuga Creek;
- The completion of groundwater sampling in the gravel sewer bed on Cory Road outside the facility's gate; and
- The performance of informal employee interviews to determine past practices at the site.

The draft RI report incorporated the results of the first three phases of site investigations. The final RI report will incorporate the data from the first three phases of site investigations as well as the results of the Phase II RI. Included in the Phase II RI were:

- The installation of three downgradient monitoring wells to the southwest (B-28M, B-29M, and B-30M) and the completion of one downgradient well to the east (B-31M);
- The completion of additional soil sampling in the SPDES outfall;
- The performance of soil gas sampling at the DoD housing facility adjacent to the western boundary of the plant; and
- The closure of subsurface tanks which contained or are thought to contain chlorinated organics.

The purpose of this section is to describe the field investigation tasks that have been performed at the Carborundum facility to verify that the work performed meets NYSDEC quality control (QC) standards. Interpretations of relevant data which have been generated from these tasks will be presented and discussed in Section 4, Nature and Extent of Contamination.

3.2 SOIL GAS SURVEYS

Three soil gas surveys were conducted at the Carborundum facility to assess chlorinated organics in the vadose (unsaturated) zone. The first survey was conducted by SOHIO during the preliminary hydrogeologic assessment in the summer of 1984. The second survey was conducted by Tracer Research Corporation, under the direction of E & E, in July 1986. The first two surveys focused on identifying the location and concentration of chlorinated organic source areas in the overburden, primarily in the vicinity of the manufacturing building. The third survey was performed in April 1990 at the DoD housing facility adjacent to the Carborundum plant. The purpose of the third survey was to determine what levels (if any) of chlorinated organics may be present in shallow soil gas at the DoD facility so that a more accurate assessment of the impact to residents at the DoD facility could be completed.

Twenty-six locations were sampled during the first soil gas survey. The sampling device consisted of 0.5 millimeter (mm) Teflon tube that was placed into a 1/4-inch polyethylene tube, which in turn was sealed with a septum. The tube was installed into a 1-inch diameter hole that was driven 4 to 5 feet into the overburden with a hollow steel pipe and sealed at the top with a clay plug. Each tube was permitted to sit for a period of 24 hours prior to withdrawing a 5-milliliter (ml) sample with a gas-tight syringe. The sample was then split and injected into two portable gas chromatographs (GCs) that were brought to the site. GC calibration was performed using TCE standards prepared at SOHIO's Warrensville, Ohio, Research Center (SOHIO 1984).

Ninety-eight soil gas samples were collected during the survey performed by Tracer Research Corporation (see Plate 1). Samples were obtained using hollow steel probes that were driven from 2 to 10.5 feet (average depth of 4 feet) into the overburden. Inserted into the hollow steel probes were polyethylene tubes which were fitted with steel reducers at the top of steel probes.

Five to 10 liters of gas were then withdrawn through the polyethylene tubes using vacuum pumps. Gas samples (10 ml) were collected during the evacuation process by inserting a syringe and needle into a silicone rubber segment of the evacuation line. Samples were immediately analyzed on site in an analytical field van equipped with a Varian

3300 GC, a Tracer 540 GC, and two Spectra Physics SP4270 computing integrators. Each sample was analyzed for TCE, trans-1,2-DCE, TCA, and PCE. Chemical standards were used throughout the sampling to ensure that the GC was properly calibrated (Tracer Research Corporation 1986).

The third survey was performed from April 27-30 and May 1-2, 1990. Samples were obtained from 2 to 4 feet below the surface. The average depth of sampling was 3 to 3.5 feet. Originally the NYSDEC-approved work plan specified that the samples be collected at 5 feet; however, it was impossible in all cases to establish air flow at this depth. Probes were driven to 5 feet and then pulled upward to establish a greater area to encourage flow. In general, this level was about 3 to 3.5 feet. This deviation was approved in the field by NYSDEC. Prior to sampling, the vacuum gauge was monitored to ensure that it had a constant reading and was not pulling atmospheric air from the surface.

A total of 47 sample points were attempted during the third survey. Only 25 of the locations had sufficient air flow to sample. The lack of flow in 22 samples is attributed to the low permeability of the soils in this area. Each sample was analyzed for TCE, TCA, VC, total 1,2-DCE, 1,1-DCE, 1,1-DCA, and MC. The detection limits were 0.00003 µg/L for TCE, 0.00005 µg/L for TCA, 0.01 µg/L for VC, 0.003 µg/L for 1,1-DCE, 0.003 µg/L for 1,1-DCA, 0.02 µg/L for 1,2-DCE, and 0.002 µg/L for MC.

Samples were collected with 7-foot by 3/4-inch sampling probes that were fitted with detachable drive points. Probes were driven to 5 feet and then pulled back about 3 feet to establish flow. Sample probes were fitted with a steel reducer and polyethylene tubing which was connected to a vacuum pump. Two to 5 liters of gas were then withdrawn from the probe to adequately purge the sampling interval. The sample interval was monitored with a vacuum gauge during purging and sampling to ensure that flow was maintained at a constant rate as an increase in rate may have indicated communication with atmospheric air.

Following purging, a 10 ml sample was collected with a glass syringe by inserting a needle inside a silicone rubber segment of the evacuation line. Samples were then analyzed in the field using a Varian 3300 GC with a flame ionization detector and an electron capture detector. The GC was calibrated on a daily basis using chemical standards for all of the analytes (Tracer Research Corporation 1990).

3.3 GEOPHYSICAL SURVEYS

Geophysical surveys were conducted in order to evaluate weathered vertical fracture zones which are potentially present beneath the facility. The United States Geological Survey (USGS) is performing an ongoing regional hydrogeologic investigation, during the course of which they have suggested that a "fracture zone" extends through the Carborundum site starting from the Niagara River and extending at least to the Lockport Dolomite escarpment (Miller and Kappel 1987). To test this hypothesis, three geophysical surveys were performed at the Carborundum facility. Each was designed to identify potential fracture zones so monitoring wells could be properly sited and to determine the bedrock configuration beneath the facility. Bedrock structure may affect contaminant movement and dispersion. Depressed areas in the top of the bedrock, for example, could indicate the location of bedrock fractures which could control transport of the groundwater.

Geophysical surveys included a seismic refraction survey conducted by Dunn Geoscience in the summer of 1986, an electromagnetic conductivity (Geonics EM34) and a VLF Survey (EM16), performed by E & E in the fall of 1987 and borehole geophysics performed at wells P-2 and P-3 in the summer of 1989.

Borehole geophysics were performed by the USGS at recovery well P-3 in June 1989. Fluid resistivity, temperature, spontaneous potential, gamma ray surveys, and caliper surveys were performed in this well. Copies of the surveys appear in Appendix A. No significant data were acquired from the surveys. USGS had also planned to run density and neutron surveys at the site; however, their density-neutron logging unit was no longer in service at the time P-3 was logged. Estimates of porosity could have been calculated from density-neutron logs. While these data may have been helpful in refining estimates of groundwater velocity, they are not regarded as absolutely essential to the conclusions presented in the RI report or ultimately to groundwater remediation.

Borehole geophysics were also attempted at production well P-2. However, high water levels in this well prevented extraction of the pump and thus, the surveys could not be performed.

3.3.1 Seismic Refraction

The seismic refraction survey was carried out over 8,800 feet in 12 survey lines. Lines were oriented east-west and north-south and were concentrated in open areas on the east and south sides of the facility. None of the seismic lines extended beyond the facility boundary. Geophone locations along the lines were generally spaced at 10-foot intervals. A 12-channel EG&G Geometrics (Model ES-1210E) seismograph was used to record seismic signals. Seismic energy was generated with a Betsy Seisgun which uses an 8-gauge industrial shotgun shell with a 3-ounce slug. Time distance plots were generated in the field and interpreted in the office (Dunn Geoscience 1986).

3.3.2 Very Low Frequency Survey

A VLF survey was conducted at the Carborundum site using the EM16/EM16R plane wave instrument. The EM16 receives radio signals generated by powerful broadcasting transmitters. These transmitters create a vertical antenna current which generates a concentric horizontal magnetic field in the subsurface. When this primary magnetic field meets more conductive bodies (i.e., metallic conductors, different soil or rock types, faults and fracture zones, etc.), a secondary magnetic field is generated and the vertical components of this field are measured by the EM16. The depth to anomalous targets is approximately equal to the horizontal distance between the maximum positive and negative readings from the instrument. The EM16R measures apparent resistivity and phase angle of the subsurface. The phase angle is used to determine whether the subsurface is homogeneous or multi-layered. The depth of penetration depends on the electrical resistivity of the subsurface material and the time it takes the VLF waves to travel through the material encountered.

EM16 data is used only to delineate vertical fractures; the technique does not distinguish between mineral-filled fractures (healed or sealed fractures) and open fractures which might be of hydrogeologic significance. The resistivity mode of the VLF instrument is used to determine the character of fractures, to help delineate groundwater plumes, and to determine the thickness of layers being investigated.

Once a fracture has been detected using the EM16, resistivity data can determine the character of the fracture. A sealed fracture will have higher resistivity than an open fracture that may contain water or chlorinated organics.

The purpose of the VLF survey at the Carborundum facility was to help delineate deep bedrock fractures. This technique has been used effectively by USGS in other areas of Niagara County in the Lockport Dolomite (Miller and Kappel 1987). The survey grid for the EM16/ EM16R was the same as that used for the EM34 survey, with profiles spaced at 100 feet and readings taken at 50-foot intervals. Cultural interferences encountered during the EM16/EM16R survey, such as metal fences and power lines, resulted in inconclusive results for this survey. Several readings could not be taken because the grid passed over paved areas which did not allow proper positioning of the probes.

3.3.3 EM34 Survey

The EM34 survey is a ground conductivity survey which measures the electrical conductivity of subsurface soil, bedrock, and groundwater. When a ground conductivity reading is taken, the instrument's transmitter coil is energized by an alternating current which produces a primary magnetic field. This magnetic field induces small currents in the subsurface which generate a secondary magnetic field in the subsurface which is sensed, along the primary field, by the receiver coil. The ratio of the secondary to the primary magnetic field is proportional to the ground conductivity. The electrical conductivity measured is a function of the soil and/or rock type, its porosity, permeability, clay content, and the conductivity of fluids filling the pore spaces.

EM techniques can be utilized to assess natural geologic and hydrogeologic conditions and aid in geologic mapping and groundwater exploration. In addition to naturally occurring situations, conductivity data can be used to delineate areas of disturbed soils such as pits and trenches, and to locate buried metal objects such as tanks, drums, or pipelines.

The transmitter and receiver coils of the EM34 can be set at varying spacings using different sets of flexible cables. Readings can be taken in the vertical and horizontal dipole configuration. In the vertical dipole mode, the coils are placed flat on the ground surface and in the horizontal dipole mode, the coils are held perpendicular to the ground surface. The coils must remain coplanar in order to obtain accurate readings. The EM34 has various depths of subsurface penetration with values depending on the intercoil spacing and the dipole configuration. Using the vertical dipole mode, 15-, 30-, and 60-meter depths of penetration can be achieved using 10-, 20-, and 40-meter coil spacings, respectively. With the horizontal dipole mode, 7.5-, 15-, and 30-meter penetration depths are possible with the same spacings.

The EM34 survey at Carborundum was divided into two survey areas covering most of the open areas surrounding the buildings on site. A grid was established on each area with transect lines trending north-northwest. A series of profiles were conducted over the grids, with profile lines spaced 100 feet apart and readings taken at 50-foot intervals. Meter readings (in millimhos per meter) were taken at each station in the vertical and horizontal dipole configuration, and with 10-, 20-, and 40-meter intercoil spacing. Readings at a few stations were not taken because of cultural interferences which affected the readings, such as metal fences and overhead powerlines.

3.3.4 Summary of Geophysical Findings

The geophysical surveys performed have, in general, provided relevant information to develop the hydrogeologic characterization at the Carborundum facility. In particular, the seismic surface refraction study provided meaningful data concerning the initial understanding of fracture orientations in the subsurface and the siting of monitoring wells along potential fractures. However, data from monitoring well sampling, core examinations, and pumping tests have, as expected, provided much more detailed information concerning the character of the bedrock aquifer media than the geophysical data. Thus, relevant conclusions presented in Section 4 will mainly utilize invasive investigation activities (i.e., drilling, groundwater sampling, water level measurements, and pumping tests) as a basis of interpretation.

3.4 MONITORING WELL AND SOIL BORING INSTALLATION

Four phases of well and boring installation have been performed at the Carborundum facility during the field investigation. This work was completed in 1984, 1986, 1988-89, 1989-90. In addition, an earlier geotechnical investigation, which involved the installation of borings and piezometers was performed in 1982 (see Table 3-2). The 1982 geotechnical investigation was completed to provide foundation information prior to the construction of the Fiberfrax plant, located on the southeastern side of the facility. While not performed to address the chlorinated organics problem at the facility, the 1982 investigation provided meaningful information concerning general characteristics of the overburden and the depth to bedrock. The location of wells and borings during all investigations performed at the Carborundum facility appear in Figure 1-2. Pertinent data regarding well and boring installation depths, depth to bedrock, thickness of the overburden, and screened intervals are presented in Tables 3-2, 3-3, and 3-4.

The purpose of well installation and soil borings was to characterize subsurface conditions beneath the facility. The specific purposes of the soil borings were to describe the stratigraphy of the overburden and to characterize source areas in the overburden. Shallow and deep bedrock monitoring wells were designed and sited to characterize the hydraulic properties and to determine the extent of chlorinated organics in groundwater of the shallow and deep bedrock aquifer, respectively.

3.4.1 1984 Well and Boring Installation

Nine soil borings, six of which were converted to shallow bedrock monitoring wells (B3M-B8M), were installed during the 1984 field investigation (see Figure 1-2 and Table 3-3). Boring and well installation was completed by R and R International under the supervision of the SOHIO Engineering Group. Installation specifications, which are depicted in Figure 3-1, were as follows:

- Borings were advanced with 3 1/4 or 4 1/4-inch hollow stem augers to the bedrock-overburden contact. Continuous split-spoon samples were collected during augering;
- The bedrock was cored with an NX-sized core barrel to 5 feet into the bedrock;
- A 5-foot, 2-inch diameter stainless steel screen was installed in the bedrock interval. The overburden section was cased with 2-inch diameter steel riser pipe;

Table 3-2

DRILLING INFORMATION SUMMARY: BOREHOLES*

Boring	Date Drilled	Total Depth	Depth to Bedrock	Surface Elevation	Rock Elevation	Comments
B-1S	2/2/82	17.2	17.2	615.4	598.2	
B-2S	2/4/82	21.8	16.3	614.2	597.9	
B-3S	2/4/82	14.7	14.7	614.4	599.7	
B-4S	2/4/82	13.0	13.0	614.0	601.0	
B-5S	2/3/82	19.6	17.0	614.6	597.6	
B-6S	2/8/82	15.5	15.5	613.8	598.3	
B-7S	2/8/82	25.0	25.0	620.4	595.4	
B-8S	2/4/82	22.0	22.0	623.5	601.5	
B-9S	2/5/82	24.2	24.2	621.5	597.3	
B-10S	4/20/82	19.6	10.1	616.5	606.4	Observation well set to 13.2′ (1-1/2")
B-11S	4/20/82	26.0	16.5	615.4	598.9	Observation well set to 24.0′ (1-1/2")
B-12S	4/21/82	24.7	19.7	614.6	594.9	--
B-13S	4/22/82	26.2	16.2	614.2	598.0	Observation well set to 24.0′ (1-1/2")
B-14S	4/22/82	26.0	16.0	613.9	597.9	--
B-15S	4/12/82	25.8	15.8	614.6	598.8	--
B-16S	4/13/82	24.5	15.5	614.0	598.5	--
B-17S	4/26/82	28.5	18.5	613.7	595.2	Observation well set at 22.0′
B-18S	4/23/82	29.0	19.0	614.5	595.5	Observation well set at 27.0′
B-19S	4/23/82	24.0	14.2	613.7	599.5	--

[AD]CZ4140:D2467, #2290, PM=15

Table 3-2 (Cont.)

Boring	Date Drilled	Total Depth	Depth to Bedrock	Surface Elevation	Rock Elevation	Comments
B-1N	4/5/82	23.0	7.0	618.4	611.4	
B-2N	4/5/82	15.7	10.7	619.0	608.3	
B-3N	4/7/82	14.0	8.7	616.6	607.9	
B-4N	4/8/82	18.4	8.4	615.5	607.1	Observation well set at 8.4′ (removed 5/6/82)
B-5N	4/6/82	18.0	13.0	621.6	608.6	
B-6N	4/1/82	15.0	10.0	621.1	611.1	Observation well set at 10.0′ (removed 5/6/82)
B-7N	4/5/82	22.8	12.0	619.5	607.5	
B-8N	4/12/82	16.3	11.3	618.0	606.7	
B-9N	4/8/82	19.0	9.0	615.7	606.7	
B-10N	4/1/82	23.0	13.0	619.5	606.5	
B-11N	4/2/82	21.0	15.8	617.6	601.8	Water at ground surface after drilling
B-12N	4/8/82	19.0	14.0	617.0	603.0	Water at ground surface after drilling
B-13N	4/9/82	30.0	20.0	615.7	595.7	Water at ground surface after drilling
B-14N	4/9/82	31.0	22.0	615.9	593.9	Water at ground surface after drilling

[AD]CZ4140:D2467, #2290, PM=15

*Geotechnical borings drilled by Empire Soils Investigations for Fiberfrax plant. All measurements in feet.

Table 3-3

DRILLING INFORMATION SUMMARY: MONITORING WELLS*

Well	Date Installed	Ground Surface Elevation (At Time of Drilling)	Total Depth (Below Ground)	Screened/Open Interval (Below Ground)	External Casing Elevation (Tripi Survey)	Internal Casing Elevation (Tripi Survey)	Depth to Bedrock (Below Ground)	Elevation of Bedrock
Shallow Bedrock Wells								
B-3M	8/21/84	623.9	24.00	19 - 24	625.87	625.59	19.0	604.9
B-4M	8/19/84	621.3	27.5	22.5 - 27.5	622.58	622.24	22.5	598.8
B-5M	8/19/84	617.9	30.0	25 - 30	620.90	620.83	25.0	592.9
B-6M	8/20/84	613.2	19.0	14 - 19	615.33	615.27	14.0	599.2
B-7M	8/21/84	614.1	20.5	15.5 - 20.5	616.22	616.22	15.5	598.6
B-8M	8/18/84	616.9	18.3	13.3 - 18.3	618.59	618.57	13.3	603.6
B-9M	11/14/86	621.3	21.5	10.0 - 20.0	623.18	623.03	10.0	611.26
B-10M	11/11/86	624.2	26.6	16.3 - 26.3	626.17	625.99	15.1	609.11
B-11M	11/12/86	620.7	22.1	12.1 - 22.1	622.77	622.81	10.4	610.34
B-12M	11/18/86	620.4	20.4	10.2 - 20.2	622.26	622.17	10.0	610.43
B-13M	11/20/86	624.0	34.2	23.5 - 33.5	626.75	626.70	23.2	600.84
B-14M	12/02/86	616.5	14.0	9.0 - 14.0	618.21	618.25	9.0	607.47
B-15M	12/08/87	623.6	23.6	13.6 - 23.6	624.55	623.98	12.3	611.3
B-16M	12/10/87	624.2	25.2	15.2 - 25.2	626.42	626.08	14.9	609.3
B-17M	8/19/88	620.5	23.8	13.8 - 23.8	622.29	621.97	12.8	607.7
B-21M	10/28/88	623.0	27.3	12.2 - 27.3	622.82	622.56	10.4	612.6

Table 3-3 (Cont.)

Well	Date Installed	Ground Surface Elevation (At Time of Drilling)	Total Depth (Below Ground)	Screened/Open Interval (Below Ground)	External Casing Elevation (Tripi Survey)	Internal Casing Elevation (Tripi Survey)	Depth to Bedrock (Below Ground)	Elevation of Bedrock
B-22M	10/28/88	622.9	36.9	21.5 - 36.8	622.47	622.29	20.8	602.1
B-23M	12/15/88	615.7	30.0	20.0 - 30.0	618.40	617.71	19.2	596.5
B-24M	12/16/88	615.2	26.5	16.5 - 26.5	617.80	617.20	15.5	599.7
B-25M	12/20/88	617.3	18.5	8.5 - 18.5	619.63	619.31	7.5	609.8
B-26M	12/19/88	615.9	28.4	18.4 - 28.4	618.61	618.06	16.9	599.0
B-27M	2/14/89	624.3	35.5	20 - 35	626.34	626.04	19.3	605.0
B-28M	12/15/89	622.9	35.0	19.5 - 34.5	623.27	622.62	17.5	605.4
B-29M	12/15/89	615.3	36.0	20.5 - 35.5	618.51	618.31	18.5	596.8
B-30M	12/15/89	610.20	38.6	23 - 38	613.51	613.33	20.3	589.9
B-31M	12/15/89	610.70	41.6	25 - 41.2	613.92	613.78	24.6	586.1
Deep Bedrock Wells								
B-18M	8/22/88	617.3	54.0	43.2 - 53.2	619.10	618.69	10.9	606.4
B-19M	8/18/88	623.9	69.5	53.8 - 68.8	626.54	626.01	22.8	601.1
B-20M	8/26/88	613.5	53.0	37.0 - 52.0	615.70	615.40	13.8	599.7
Production and Pumping Wells								
P-1	?	--	?	?	--	--	?	?
P-2	?	617.0	50(?)	?	618.16	618.16 (no pipe)	?	?
P-3	10/31/88	623.9	60	22.8 - 60	624.90	624.90 (no pipe)	20.4	603.5

*All measurements in feet.

Table 3-4

DRILLING INFORMATION SUMMARY
ENVIRONMENTAL BORINGS DRILLED FOR SOURCE DELINEATION*

Depth R & R Drilling	Date Drilled	Total Depth	to Bedrock	Surface Elevation	Rock Elevation	Notes
Preliminary Groundwater Investigation Borings Drilled by R & R International (SOHIO Study)						
B-1 (BH)	8/21/84	13.3	13.7	620.5	606.8	Borehole drilled by R & R and not made into MW
B-2 (BH)	8/16/84	10.5	10.5	621.1	610.6	Borehole drilled by R & R and not made into MW
B-9 (BH)	8/21/84	15.0	15.0	617.5	602.5	Borehole drilled by R & R and not made into MW
Second Groundwater Investigation Borings Drilled by Empire Soils Investigation (E & E Study)						
BH-1	11/25/86	9.1	9.1	620.54	611.44	OVA = 0.3 PPM @ 8'
BH-2	11/25/86	11.2	11.2	618.79	607.59	OVA = 100 PPM @ 8' - 10'
BH-3	11/26/86	12.3	12.3	618.40	606.10	OVA = 2.4 PPM @ 8' - 12'
BH-4	11/26/86	13.3	13.3	617.21	603.91	OVA ≅ 3 PPM @ 8' - 12'
BH-5	11/26/86	17.3	17.3	615.82	598.52	OVA = 15 PPM @ 8' - 10'
BH-6	12/3/86	17.4	17.4	616.34	598.94	OVA = 153 PPM @ 14' - 16'; 6' - 14' = 10 - 60 PPM
BH-7	12/3/86	16.4	16.4	617.49	601.09	OVA = 30 - 50 PPM @ 8' - 10'
BH-8	12/2/86	14.0	14.0	619.90	605.90	OVA = 70 PPM @ 0' - 2'; 10 PPM @ 8' - 10'
BH-9	12/2/86	12.6	12.6	620.06	607.46	OVA = 100 PPM @ 8' - 10'; 4' - 12' = 50 PPM
BH-10	12/1/86	13.1	13.1	620.40	607.30	--

*All measurements in feet.

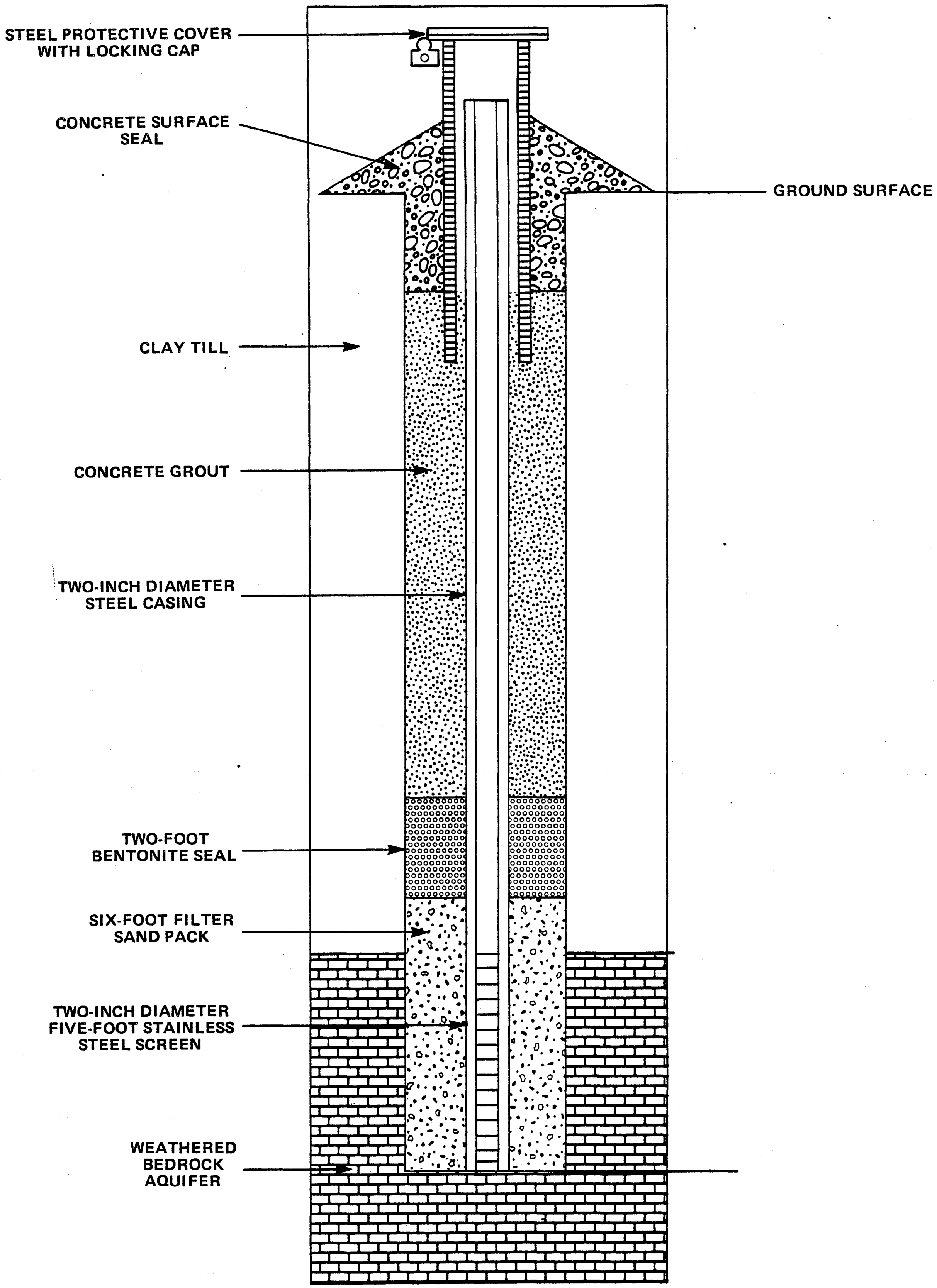


Figure 3—1 MONITORING WELL CONSTRUCTION FOR SHALLOW WELLS (B3M — B8M)

- A coarse silica sandpack was placed within and 1 foot above the screened interval. A 2-foot bentonite seal was placed adjacent to the riser pipe immediately above the sand pack. The remainder of the well annulus was grouted with concrete grout. Four-inch diameter locking steel casing with a 2-foot stickup was placed at the surface. The protective casing was secured with a sloping concrete pad; and

- Wells were developed with a bailer for a minimum of 1 hour. Excessively turbid wells were developed until relatively free of silt and clay.

Soil samples were collected from each 2-foot split-spoon interval and placed in 40-ml glass volatile organic analysis (VOA) vials. The samples were transferred to SOHIO's Research and Development Center Laboratory in Warrensville, Ohio. Soil samples were analyzed for volatile organics by static headspace gas chromatography with a Perkin-Elmer Automated F-45 Automated Headspace Analyzer. Falling head slug tests and double packer constant head tests were performed on newly installed monitoring wells and production well P-2, respectively, for the purpose of initially estimating bedrock aquifer parameters.

3.4.2 1986 Well and Boring Installation

Eleven soil borings (BH-1 through BH-11) and six shallow bedrock monitoring wells (B-9M through B-14M) were installed during the 1986 field investigation (see Figure 1-2 and Tables 3-3 and 3-4). These borings, which were primarily sited in suspected source areas, as determined from the 1984 SOHIO study and the 1986 soil gas survey, were designed to characterize chlorinated organics in the overburden. Monitoring wells were located in likely vertical fracture areas as interpreted from the seismic refraction survey. Installation specifications, which are depicted in Figure 3-2, proceeded as follows:

- An 8-inch borehole was drilled with hollow-stem augers through overburden until the weathered bedrock surface was reached. Continuous split-spoon samples were collected and described over this interval;

- For monitoring wells, the boring was then advanced into bedrock by rock coring with an NQ-sized core barrel. Coring was terminated at about 11 feet into bedrock;

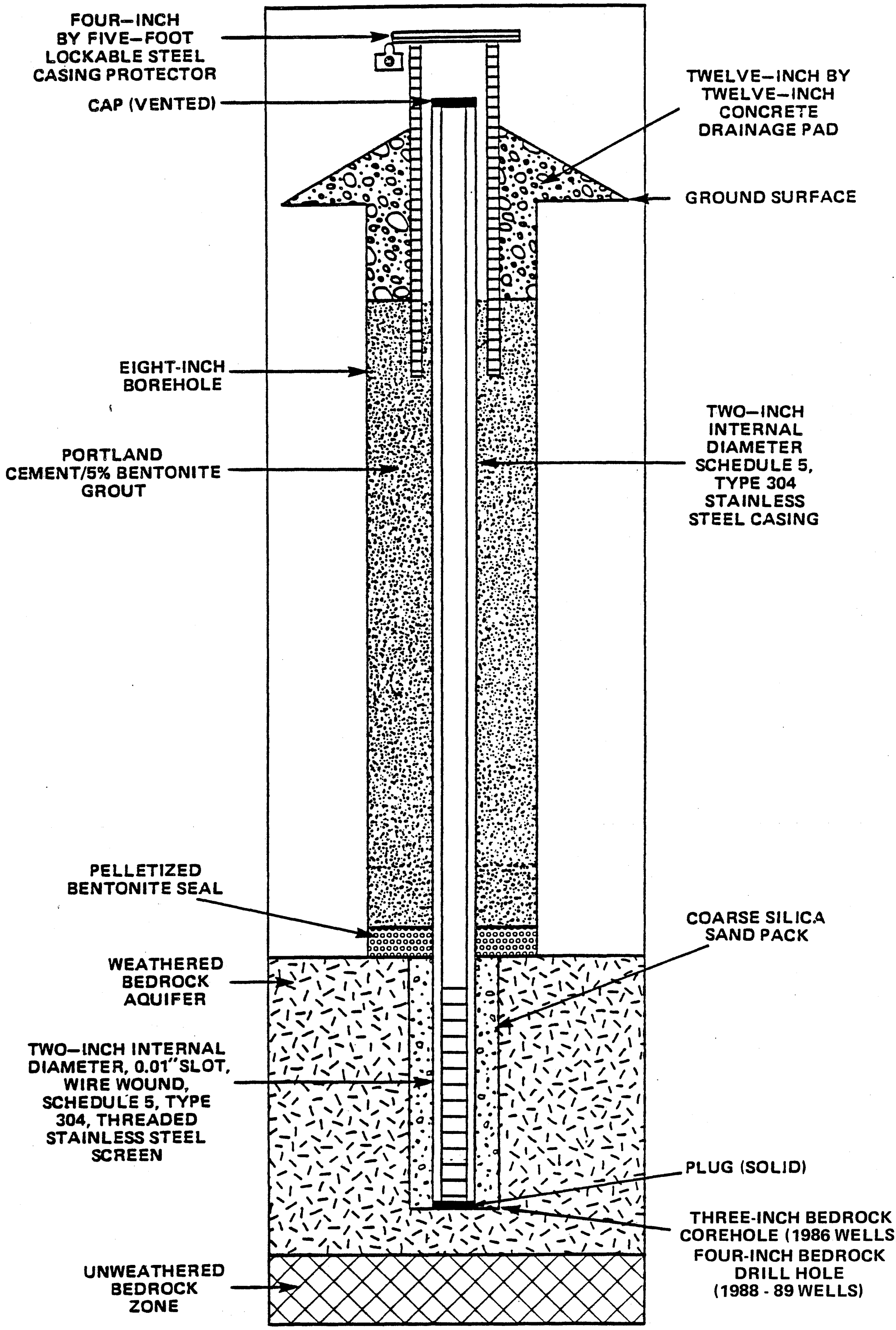


Figure 3–2 MONITORING WELL CONSTRUCTION FOR SHALLOW WELLS (B9M – B17M AND B21M – B31M)

- A 10-foot-long, 2-inch inner diameter (ID), Schedule 5, Type 304, flush joint, stainless steel screen was placed in the 3-inch core hole from the total depth to about 1 foot beneath the bedrock-overburden interface. The balance of the borehole was cased with 2-inch stainless steel riser pipe (Schedule 5, Type 304). The riser pipe was capped and extended about 2 feet above grade;

- A coarse silica sandpack was trimmed to 1 foot above the top of the screened interval. A 1-foot bentonite seal was placed above the sandpack. The balance of the well annulus was then cemented with a 5% bentonite/cement grout; and

- A 4-inch diameter, 5-foot long section of locking steel surface casing was installed at the surface. The surface casing was secured with a concrete pad, the upper surface of which was sloped away from the well casing.

Composite soil samples were collected from boreholes 1-9 (BH-1 through BH-9) at 4-foot intervals. Each sample was composited in stainless steel bowls, and placed in two 40-ml glass VOA vials. Samples were sent to Recra Environmental, Inc. (Recra) and analyzed for a selected list of chemicals as per EPA Method 601. Included on the selected list were carbon tetrachloride, chloroform, 1,1-DCA, 1,1-DCE, total-1,2-DCE, MC, TCA, TCE, and VC.

3.4.3 1988-89 Well Installation

Ten additional shallow bedrock monitoring wells, three deep bedrock monitoring wells, and one potential groundwater recovery well were installed in 1988-89. The locations of the wells are depicted in Figure 1-2. The purpose of the shallow wells was to:

- Monitor shallow bedrock groundwater to the north of the facility, which is considered to be upgradient (B-15M and B-16M);

- Monitor shallow bedrock groundwater quality in potentially downgradient locations to the west and south of the facility (B-21M through B-26M);

- Monitor shallow groundwater quality on the western portion of the facility in a suspected source area (B-17M) and in an area of unusual bedrock heterogeneity (B-27M) where P-3 had only limited hydraulic influence on B-3M during preliminary pump tests; and

- Further refine hydraulic characteristics of the shallow bedrock aquifer (all shallow wells).

Deep bedrock wells (B-18M, B-19M, and B-20M) were designed to monitor groundwater quality and deeper bedrock characteristics in the next fracture zone beneath the weathered bedrock zone into which the shallow wells had been installed (see Figure 3-3). A large diameter recovery well (P-3) was also installed at the western side of facility during this phase of work. The purpose of P-3 was to determine the groundwater capture area on the western side of the facility by performing a long-term (24 hours or greater) pumping test at this location. If results of the pump test demonstrated a sufficient capture area, this location may be used as a groundwater recovery point during the groundwater remediation program.

Design of shallow wells for the 1988-89 investigation is identical to the 1986 shallow well design with two exceptions. First, the borehole was reamed to a diameter of 4 inches to better accommodate the sandpack. Second, perimeter wells drilled in the western and southern portion of the site were cored and screened 15 feet into the shallow bedrock interval.

Each deep well which was paired with a shallow well was designed to determine vertical hydraulic gradient and to determine the concentration of chlorinated organics in the deeper bedrock aquifer. Well installation proceeded as described for shallow well installation, with the following exceptions:

- The diameter of the cased borehole was 8 inches in the overburden and 6 inches in the bedrock;
- The diameter of the screened borehole was 4 inches;
- A 4-inch galvanized steel liner was placed from the surface through the weathered bedrock and to the top of the first permeable interval encountered below the surface; and
- Only the first permeable rock interval as determined from packer injection tests and core examination beneath the weathered bedrock zone was screened.

The specifications for the installation of the 8-inch diameter extraction well (P-3), as depicted in Figure 3-4, were as follows:

- A 12-inch borehole was drilled with air rotary methods to the weathered bedrock-overburden interface. A 12-inch

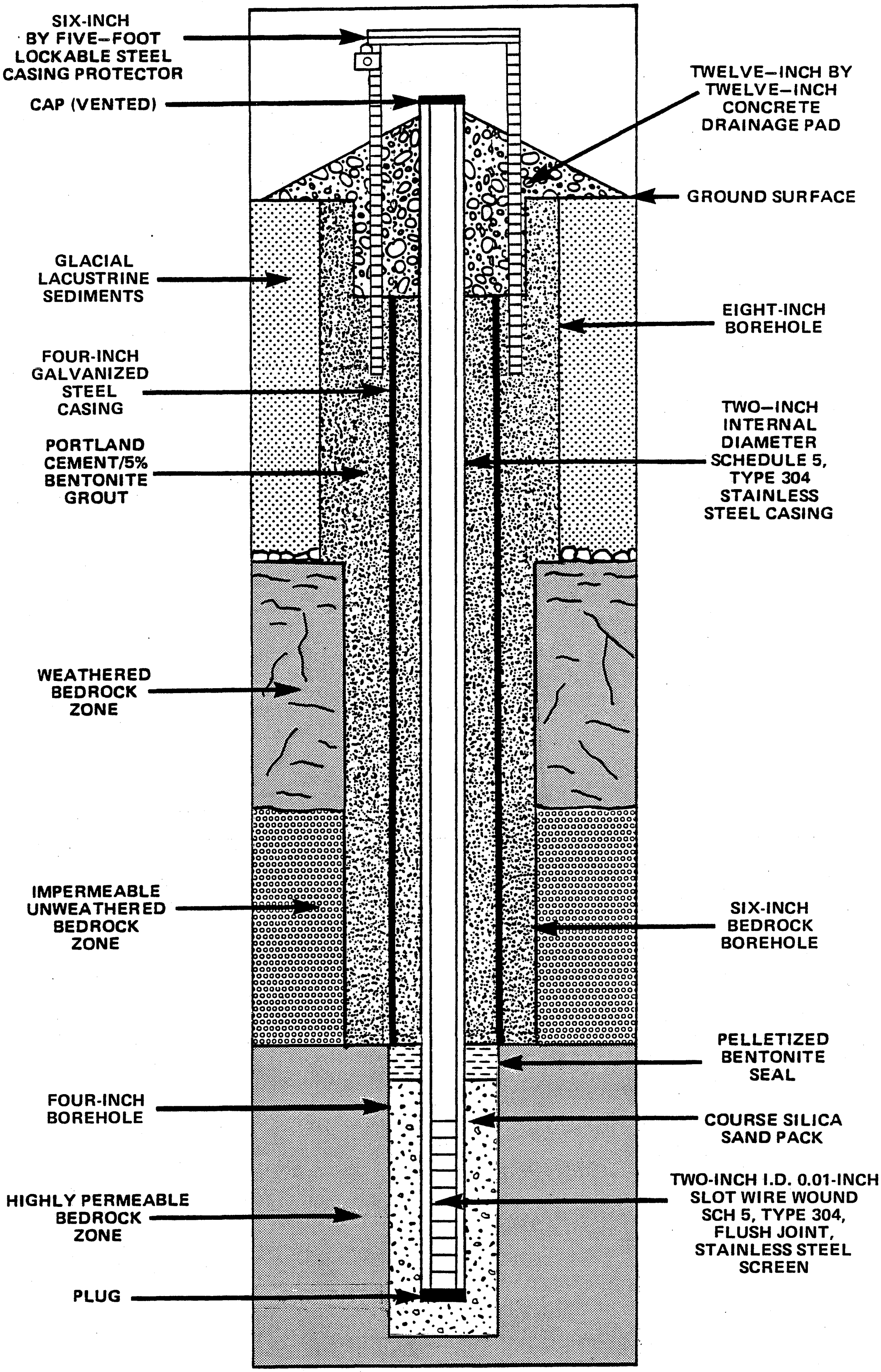


Figure 3–3 MONITORING WELL CONSTRUCTION FOR DEEPER WELLS (B18M – B20M)

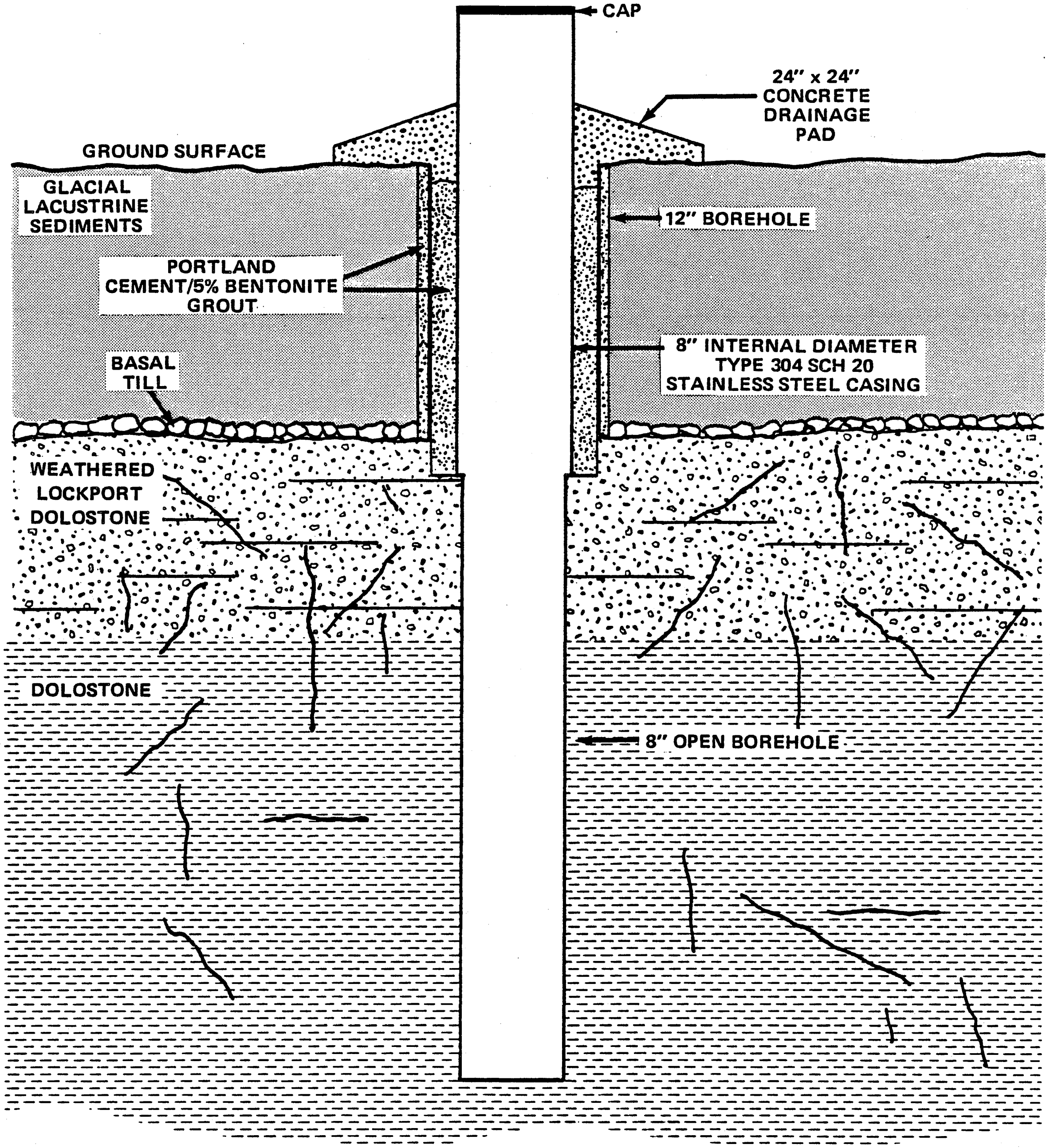


Figure 3–4 PUMPING WELL CONSTRUCTION

temporary steel liner was driven into the drill hole to prevent collapse in the overburden interval;

- The bedrock-overburden interface was encountered at 20.4 feet below grade. The 12-inch borehole was then extended to 22.8 feet and 8-inch diameter Type 304, Schedule 20 stainless steel casing was grouted from 22.8 feet to surface. The 12-inch temporary steel liner was progressively extracted during the grouting process. Grout was allowed to set overnight;
- The borehole was then NQ-cored to 71 feet below grade. Packer injection tests were performed at 5- to 10-foot intervals during coring to qualitatively assess bedrock permeability;
- Based on examination of the bedrock cores and evaluation of the packer tests, the well was reamed to 7 7/8 inches by air rotary methods to 60.0 feet; and
- A 2-hour production test was then performed to verify that the well would produce at a minimum rate of 50 gpm, which was regarded as a rate sufficient to perform a full-scale pumping test at this well. The production test also served as a means to develop the pumping well.

3.4.4 1989-90 Well Installation

Four additional shallow bedrock monitoring wells (B-28M through B-31M) were installed in 1989-90. The locations of these wells are shown in Plate 2. The purpose of wells B-28M, B-29M, and B-30M were to further define the extent of downgradient chlorinated organic migration in the shallow bedrock aquifer to the west (B-28M), southwest (B-29M), and south-southwest (B-30M). The purpose of well B-31M was to investigate the potential for dispersion of the groundwater plume to the east, near the residences along Walmore Road.

Design of the 1989-90 wells is identical to the 1988-89 shallow well design.

3.5 PUMPING TESTS

Two full-scale (minimum time of 24 hours) pumping tests have been performed at the Carborundum facility. The first test was conducted at well P-2 in December 1986. The second test was conducted at well P-3 in April 1989. Two 8-hour pumping tests were also performed at well P-3 in January and February of 1989 to verify that the well had sufficient capacity to justify a full-scale test. The purpose of the full-scale tests was to estimate hydraulic parameters of the bedrock aquifer, including hydraulic conductivity, transmissivity, storativity, capture area, and maximum sustainable pumping rates. Detailed discussions of procedures and interpretations appear in reports prepared for Carborundum for each test. Pumping test interpretations are incorporated into Section 4 of this document. Pumping test procedures are outlined in the following narrative. Data for both pumping tests are presented in Appendix B.

The first pumping test was performed at well P-2 during the week of December 11-14, 1986. Prior to the onset of pumping, a packer was set 15 feet beneath the overburden-bedrock interface to isolate the weathered bedrock portion of the aquifer from the deeper aquifer. Well P-2 was pumped at an average rate of 372 gpm during the test period, which was 24 hours. Pump discharge rates were recorded with an orifice weir. Water was discharged during the test with 4-inch diameter pipe into the facility's sewer system, then to the Niagara County Sewer District 1 Sewage Treatment Plant. Water samples were collected at the beginning of the test and at 4-hour intervals thereafter. These samples were analyzed for volatile organics with EPA Method 601 to estimate average contaminant levels from well P-2, to be used as a basis for remedial design and to verify that water transported to the sewer system did not exceed average effluent volatile organic levels agreed to by Carborundum and the Niagara County Sewer District 1.

An In Situ SE 2000 16-channel data logger and 13 transducers were used to monitor drawdown in P-2, monitoring wells B-3M through B-13M and discharge rates at the orifice weir. Aquifer parameters were estimated with semi-log plots of time versus drawdown (Jacob Straight Line Analysis) and with semi-log distance drawdown graphs. Aquifer recovery was monitored for a period of 21 hours after the test. Barometric pressure was also monitored during the test through data collected at the Niagara Falls International Airport.

The design of the second pumping test, which was performed at P-3 during the period from April 21-28, 1989, was essentially the same as the first test at P-2. Variations between the two tests were primarily related to the monitoring well network and the specific capacity of P-3. A summary of the variations is as follows:

- P-3 was pumped at a rate of 90 gpm for 38 hours. Discharge rates at P-3 were monitored with both a Pitot tube and a transducer which were both integrated into the orifice weir. A packer was set 22 feet beneath the bedrock-overburden interface to isolate the weathered bedrock from the deeper aquifer for the same reason as was explained for the pumping test at P-2. Bedrock cores were examined to determine an unfractured section of the borehole in which to set the packer;

- Wells B-3M, B-4M, B-6M, B-9M, B-10M, B-12M, B-13M, B-17M, B-19M, B-21M, B-22M, B-23M, B-27M, and P-3 were monitored with two 8-channel SE-2000 In Situ data loggers. The majority of other wells at the facility were monitored by hand with an audible water level indicator at 1- to 4-hour intervals. (The monitoring well network for the P-3 test varied from the P-2 test because P-3 was designed to characterize the western portion of the facility);

- The recovery test was performed for a period of 48 hours for most wells monitored with transducers. Additional recovery data was also obtained by hand 96 hours after termination of the drawdown test;

- Barometric pressure and aquifer response were monitored for 48 hours prior to test initiation in order to determine the natural barometric efficiency of the aquifer and to properly correct for barometric fluctuations;

- The facility's discharge to the Niagara County Sewer District 1 was sampled every 2 hours during the test. These samples were immediately delivered to the laboratory and screened for 10 chlorinated organics to determine compliance with the effluent limits set by the sewer district. Four-hour samples were also taken of the pump's effluent and the plant's effluent and analyzed later to determine chlorinated organic levels of discharge waters; and

- Test data was reduced and interpreted by use of Groundwater Analysis Package (GWAP) software program, which is an analytical computer program that uses log-log curve matching techniques.

3.6 MONITORING WELL DEVELOPMENT

Monitoring well development has been performed at all wells installed on and in the vicinity of the facility (see Appendix A). Wells installed during the first field investigation were developed with bailers. Well development during the second phase of drilling was accomplished by compressed air. Development was accomplished during the third phase of drilling by the use of bailers or hand pumping. The two-hour production test at P-3 also provided a means to develop this well.

Well development, in general, proceeded for a period of 1 hour. Wells which had excessive turbidities, as estimated visually, were developed for longer periods until relatively free of silt and clay.

Thirteen monitoring wells on site were determined to require redevelopment for one of two reasons: the average turbidity of the groundwater in the well for the first three quarters of 1989 was greater than 100 nephelometric turbidity units (NTU) or one foot or more of sediment had accumulated in the bottom of the well. Redevelopment took place on October 25 through November 1, 1989 and included wells B-3M, B-4M, B-5M, B-6M, B-7M, B-8M, B-13M, B-18M, B-19M, B-22M, B-23M, B-25M, and B-26M (see Appendix A). Well development was accomplished using compressed air. Ten of the thirteen wells were developed until the turbidity of the water was less than 100 NTU. Development of wells B-4M and B-25M was stopped before turbidities were below 100 NTU after purging 3 gallons and 2.5 gallons, respectively, due to low production rates. The development of B-5M was stopped after purging 100 gallons since the turbidity of the water was still above 100 NTU.

3.7 GROUNDWATER SAMPLING

Quarterly groundwater sampling has been performed at the Carborundum facility since March 1985, after the initial monitoring wells were installed. Additional wells have been added to the quarterly sampling program as they were installed. Sampling practices used at the facility are as follows:

- Prior to sampling, water levels are measured in all wells. Each well is then purged of three to five times the volume of groundwater standing in casing. The water level is then remeasured;

- Samples are then collected with bottom-filling dedicated stainless steel bailers, with Teflon check balls;

- Each sample for chemical analysis is carefully transferred into 40 ml glass VOA vials. A separate sample is collected for field measurement for pH, conductivity, and turbidity;

- Any unusual characteristics are recorded; and
- The samples are shipped to the laboratory following chain-of-custody procedures.

In addition to normal quarterly groundwater sampling, two specialized groundwater sampling techniques have been implemented. The first technique was designed to determine if DNAPL may exist at the facility. To complete this sampling, a stainless steel Bacon Bomb Sampler was used to acquire samples from the bottom of monitoring wells B-8M and B-17M. These wells were selected because they monitor the groundwater containing the highest levels of chlorinated organics at the facility and are screened in bedrock beneath two suspected source areas. Groundwater was not purged from these wells prior to sample collection.

The second groundwater sampling technique was designed to determine if groundwater containing chlorinated organics may be preferentially migrating along the gravel bed beneath the sewer line on Cory Road. A stainless steel well point was installed adjacent into the gravel bed of the sewer line to a depth of 10 feet (the well point was screened from 5 to 10 feet). Twenty volumes of purge water from the well point were evacuated and a sample collected. NYSDEC split samples with Carborundum to perform a more detailed analysis using Target Compound List (TCL) organics and Target Analyte List (TAL) metals.

3.8 PRIVATE WELL AND SUMP SAMPLING

Residential sampling was performed in September 1985, May 1988, and again in December 1988, to verify that the groundwater plume had not impacted any private residences in the vicinity of the site. The 1985 and May 1988 private well sampling was performed by the Niagara County Department of Health. Samples from 22 private residences were analyzed during the 1985 and May 1988 sampling. Samples were obtained with pre-cleaned top-filling stainless steel bailers. Wells were not purged prior to sampling. Analysis was performed by EPA Method 601.

E & E completed the December 1988 sampling of private wells and sumps during which a total of 47 well samples, 41 sump samples, and one creek sample were collected. Procedures implemented in the December 1988 sampling were as follows:

- Samples from sumps, if water bearing, were obtained after the water in the sumps was evacuated and the sump was allowed to recharge for 5 minutes. Samples were collected by dipping two 40-ml VOA vials in the sump;

- Samples from active wells were collected by turning on a cold water spigot. The well was purged for 10 minutes after the pump was engaged. After 10 minutes, samples were collected from the spigot. Each sample was placed in 40-ml VOA vials; and

- Samples from inactive wells were obtained with pre-cleaned stainless steel bailers and 40-ml VOA vials. However, inactive wells were purged with a surface centrifugal pump for 10 minutes. A large diameter (4-inch) polyvinyl chloride (PVC) bailer was used to purge the well if the well depth exceeded the depth from which the surface pump could effectively operate.

3.9 QUARRY SEEP SAMPLING

Seep samples from the Medina Sandstone Corporation quarry, which extracts Lockport Dolomite bedrock and is located about 0.5 mile west-southwest of the Carborundum facility, were analyzed by Recra in December 1986. The purpose of the sampling was to determine if the groundwater plume, which is moving southwest, may have reached the quarry. Ten samples were collected from the quarry wall. Access to the quarry wall was obtained by means of a man lift mounted on a truck. Samples were placed in 40-ml VOA vials and analyzed with EPA Method 601.

3.10 SEDIMENT AND SURFACE WATER SAMPLING

Sediment and, where possible, surface water samples were collected from the inactive SPDES outfall and from Cayuga Creek to determine if chlorinated organics are present in either the outfall or the creek. The sampling was performed during the week of July 10-14, 1989. Sample locations, which are depicted on Figure 3-5, were as follows:

- Two sediment samples along the SPDES outfall within the facility;

- One sediment sample along the SPDES outfall between the eastern facility boundary and the point at which the outfall enters Cayuga Creek; and

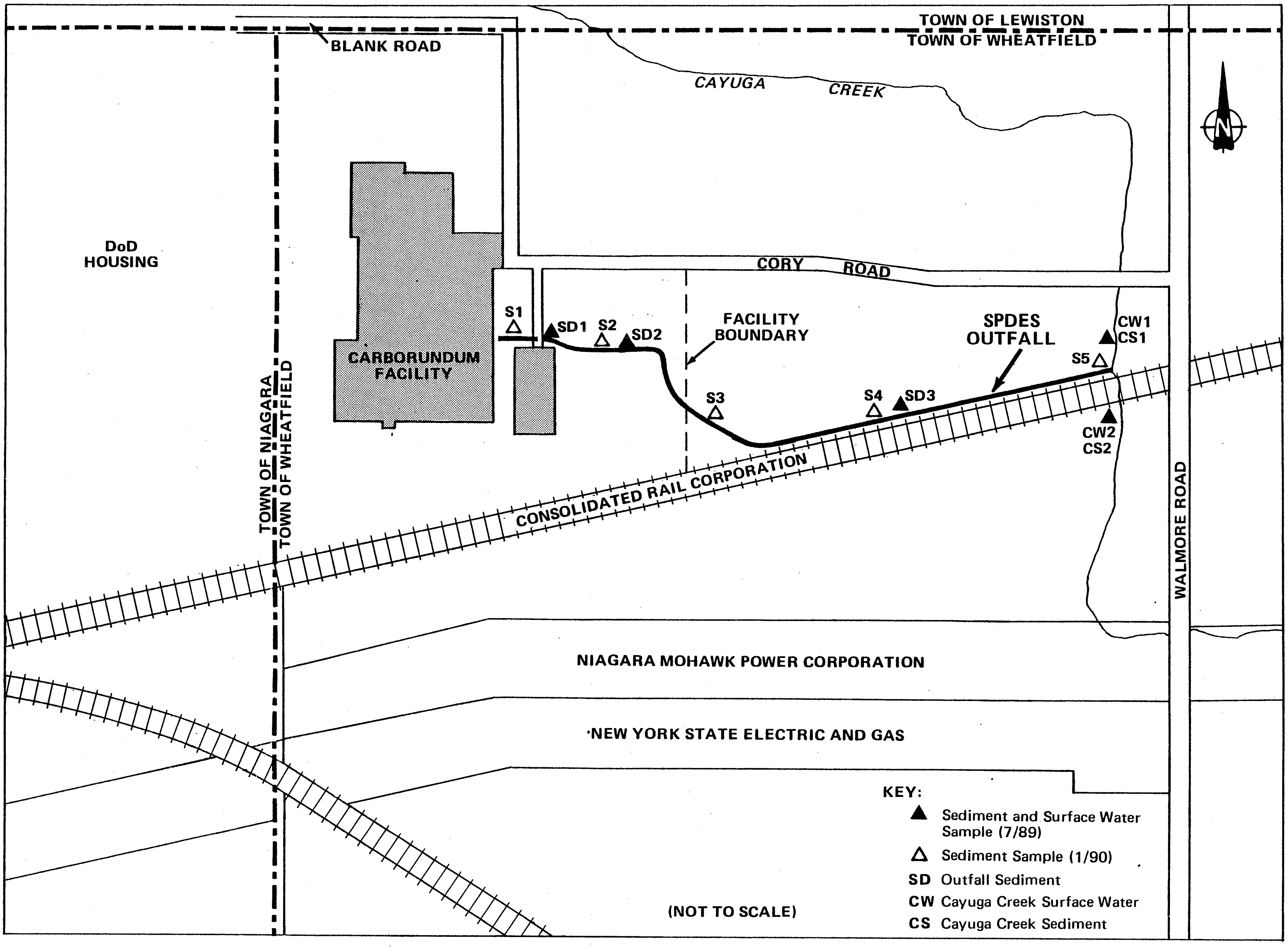


Figure 3–5 SEDIMENT AND SURFACE WATER SAMPLING LOCATIONS

- Two sample sets (sediment and surface water) in Cayuga Creek, immediately north and south of where the SPDES outfall enters Cayuga Creek.

Each sediment sample was collected with a pre-cleaned stainless steel spoon. The samples were transferred into 40-ml VOA vials. Surface water samples were collected by submerging 40-ml VOA vials directly in the stream. Samples were analyzed by EPA Methods 5030 and 8010.

During the Phase II RI, additional samples were taken from five locations along the inactive SPDES outfall. The sampling was performed during the week of January 22-26, 1990, by Advanced Environmental Services and sample locations are shown on Figure 3-5.

Two samples were collected at each sampling location at depths of 6 inches and 3 feet. To collect the samples, a 1-inch steel probe was driven into the ground to the depth of sampling. The probe was then removed and a 1-inch diameter open sleeve stainless steel sampler was driven into the sample interval. This sampler was then removed and the sample was transferred into 40-ml VOA vials. The samples were analyzed by EPA Method 8010.

3.11 TANK SAMPLING AND CLOSURE

Sampling of septic tanks was performed in May 1987 and in June 1989. The sampling was designed to determine if the tanks were potential sources of chlorinated organics. Dependent on the results, the tank contents would be removed, tanks would be cleaned, and the tanks either excavated or filled with an inert and impermeable material. During the first sampling round, liquids in the tanks were sampled with a stainless steel Pacs Bomb Sampler. No sludge samples were taken. A stainless Bacon Bomb Sampler and a Wheaton Grab Sampler were used to obtain liquid and sludge samples, respectively, during the second round of sampling.

A total of 12 liquid samples were collected in May 1987. Samples were analyzed for a restricted list of chlorinated organics using EPA Method 601, as described in Section 3.12. Sixteen septic tank samples (12 liquid and four sludge) were collected during the second sampling round. This included a resampling of tanks 8, 9, 10E, and 10W when the initial sampling of the liquid at the top of the tanks resulted in lower than expected levels of chlorinated organics based on the May 1987 results. Subsequent samples were taken for reanalysis from the bottom of the liquid layers with the stainless steel Bacon Bomb Sampler.

All samples were analyzed for organics using EPA Methods 5030 and 8010 and for polychlorinated biphenyls (PCBs). In addition, the following specific sampling techniques were used to characterize the wastes proposed for off-site disposal:

- PCBs, total solids, and a restricted list of metals (arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver) from sludge samples in tanks 6, 7, 10W, and a composite liquid sample from tanks 8, 9, 10E, and 10W; and
- Percent ash, British thermal units (BTU), total cyanide, flashpoint, percent organic sulfur, and pH from the composite liquid sample from tanks 8, 9, 10E, and 10W.

Closure of all subsurface tanks (see Figure 4-3) was completed at the plant from October 30, 1989 to November 3, 1989. Tank closure, which was completed by Sterling Environmental, was necessary because the tanks contained varying levels of chlorinated organics which were suspected to be source areas. This is particularly true of tanks 8, 9, and 10 which contained very high levels of chlorinated organics (see Table 4-4).

Liquid and sludge contents were removed from all tanks, the tanks cleaned with high pressure water, and then backfilled with concrete and a 3% bentonite slurry. Tank liquids were put into a large tanker and sewered at a constant rate according to the agreement between Carborundum and the Niagara County Sewer District 1. Sludge was contained in 17-H drums and disposed of in an appropriate manner.

3.12 DATA VALIDATION

Data validation has been performed by E & E for Carborundum since E & E became involved in the project in March 1986. Analysis of samples had been performed by Recra from the inception of quarterly groundwater sampling until December 1988. Since January 1989, Advanced Environmental Systems, Inc., has performed sample analysis for Carborundum. Data analyzed during the project appears in Appendix C.

From 1985 through 1988, samples were analyzed using a restricted list of compounds from EPA Method 601. Included in this list were carbon tetrachloride, chloroform, 1,1-DCA, 1,1-DCE, total-1,2-DCE, MC, 1,1,1-TCA, TCE, and VC. At the request of NYSDEC in November 1988, Carborundum changed the analytical method employed at the site to EPA Methods 5030 and 8010 (see Table 3-5). The list of compounds from this technique is more extensive than previously under the restricted EPA 601 list. In general, quality assurance/quality control (QA/QC) samples used to validate samples for the various sample media include:

- 10% field duplicates;
- 10% field and trip blanks;
- Matrix spike and matrix spike duplicate samples; and
- Appropriate internal QA/QC samples as required under Methods 5030 and 8010.

Additional sampling that has been performed at the facility includes the analysis of groundwater from wells P-2 and B-3M in April 1987 for EPA priority pollutants, soluble metals, lead, iron, manganese, and zinc, and analysis of groundwater from well B-17 by NYSDEC in January 1989 for EPA TCL (volatile organics, base/neutral and acid extractables, pesticides, and PCBs), TAL (23 metals and cyanide), and tentatively identified compounds.

3.13 DECONTAMINATION

All decontamination has been performed in accordance with NYSDEC-approved procedures. Sampling methods and equipment were chosen to minimize decontamination requirements and to prevent the possibility of cross contamination (i.e., dedicated equipment was used when possible). All drilling equipment was decontaminated prior to drilling, after drilling each monitoring well, and after the completion of all monitoring wells. Drilling decontamination consisted of:

- Initial steam cleaning;
- Scrubbing with brushes if soil remained on equipment; and
- Final steam cleaning.

Table 3-5

LIST OF COMPOUNDS ANALYZED UNDER METHODS 5030 AND 8010 WITH QUANTIFIABLE DETECTION LIMITS

Compound	Quantifiable Detection Limit* (ug/L)
Bromoform	2.0
Bromomethane	11.8
Carbon Tetrachloride	1.2
Chlorobenzene	2.5
Chloroethane	5.2
Chloroform	0.5
2-Chloroethyl vinyl ether	1.3
Chloromethane	0.8
Dibromochloromethane	0.9
1,2-Dichlorobenzene	1.5
1,3-Dichlorobenzene	3.2
1,4-Dichlorobenzene	2.4
1,1-Dichloroethane	0.7
1,2-Dichloroethane	0.3
1,1-Dichloroethylene	1.3
trans-1,2-Dichloroethene	1.0
cis-1,2-Dichloroethene	1.0
1,2-Dichloropropane	0.4
trans-1,3-Dichloropropylene	2.0
Methylene chloride	2.5
1,1,2,2-Tetrachloroethane	0.3
Tetrachloroethylene	0.3
1,1,1-Trichloroethane	0.3
1,1,2-Trichloroethane	0.2
Trichloroethene	1.2
Vinyl chloride	1.8

[AD]CZ4140:D2467, #2382, PM=0

*Quantifiable detection limits within this table can be adversely affected by matrix interferences and/or high concentration within the samples.

Reference: "Test Methods For Evaluating Solid Wastes," SW 846, Third Edition, September 1986 (see Tables 1 and 2, pages 8010-2 and 8010-3).

Nondisposable equipment, such as split spoons, were decontaminated between each sampling event. Decontamination of nondisposable sampling equipment consisted of:

- Scrubbing with brushes in a detergent solution;
- Rinsing with deionized water;
- Rinsing with acetone (performed for organics analysis only);
- Triple rinsing with deionized water; and
- Air drying.

Dedicated stainless steel bailers, which are used for groundwater sampling, were decontaminated with a detergent solution and rinsed with copious amounts of deionized water. Acetone was not be used for bailers because of the potential for volatile contamination in the internal portion of the bailer.

3.14 EMPLOYEE INTERVIEWS

Informal employee interviews were performed by Carborundum to document past handling practices of TCE and verify that additional source areas do not exist at the facility. The pertinent results of the interviews will be presented in Section 4.

4. NATURE AND EXTENT OF CONTAMINATION

The primary compounds of concern at the Carborundum facility in the Town of Wheatfield, New York are a limited number of chlorinated organics and their degradation products. The most commonly used chlorinated organic was TCE. TCA and carbon tetrachloride have also been used at the facility. TCA is still used in the graphite furnaces. Carbon tetrachloride is no longer in use. MC has been used at the facility in small quantities since July 1988 and as such is not considered a source of chlorinated organics.

TCE, TCA, and carbon tetrachloride are present in the groundwater and, to a more limited extent, in subsurface soils beneath the facility. Only very low concentrations of MC have been found in the groundwater. The primary degradation products also found include cis- and trans-1,2-DCE, 1,1-DCE, and VC, which are all derived from TCE; DCA, which is derived from TCA; and chloroform and MC, which degrades from carbon tetrachloride. (1,1-DCE may also be derived from TCA.) Insignificant concentrations of tetrachloroethene, a parent compound to TCE, were also found. It is also possible that these compounds were impurities in the TCE, TCA or carbon tetrachloride that were used at the facility.

Chlorinated organics in the overburden soils in suspected source areas have been detected at significant levels. The maximum concentration found in the soil borings was 66 ppm of TCE (see Tables 4-1 and 4-2). However, chlorinated organics in the overburden are more spatially restricted than in the bedrock because the overburden soils have very low permeability, which causes migration rates to be slow, and because the suspected source areas are quite localized.

The primary medium of concern beneath the plant is the groundwater in the upper 20 feet of bedrock. The highest concentration of

Table 4-1

ANALYTICAL SUMMARY:
BOREHOLE SOILS DATA
AUGUST 1984
(ppm)

Borehole Depth (Ft.)	Carbon Tetrachloride	Chloroform	Trichloroethene	1,1,2,2-Tetrachloroethane
B-1 (BH)				
0-2	<0.010	<0.010	0.030	<0.010
4-6	<0.010	<0.010	<0.010	<0.010
8-10	<0.010	<0.010	<0.010	<0.010
B-2 (BH)				
0-2	<0.010	<0.010	ND	<0.010
4-6	<0.010	<0.010	ND	<0.010
8-10	<0.010	<0.010	ND	<0.010
B-3 (BH)*				
0-2	<0.010	<0.010	ND	<0.010
4-6	<0.010	<0.010	ND	<0.010
8-10	<0.010	<0.010	ND	<0.010
12-14	<0.010	<0.010	ND	<0.010
18-20	<0.010	<0.010	ND	<0.010
B-4 (BH)*				
0-2	<0.010	<0.010	ND	<0.010
4-6	<0.010	<0.010	ND	<0.010
8-10	<0.010	<0.010	ND	<0.010
12-14	<0.010	<0.010	ND	<0.010
16-18	<0.010	<0.010	ND	<0.010
20-22	<0.010	<0.010	ND	<0.010
B-5 (BH)*				
0-2	<0.010	<0.010	ND	<0.010
4-6	<0.010	<0.010	ND	<0.010
8-10	<0.010	<0.010	ND	<0.010
12-14	<0.010	<0.010	ND	<0.010
16-18	<0.010	<0.010	ND	<0.010
20-22	<0.010	<0.010	ND	<0.010

Table 4-1 (Cont.)

Depth	Carbon Tetrachloride	Chloroform	Trichloroethene	1,1,2,2-Tetrachloroethane
B-6 (BH)*				
0-2	<0.010	<0.010	ND	<0.010
4-6	<0.010	<0.010	ND	<0.010
8-10	<0.010	<0.010	ND	<0.010
12-14	<0.010	<0.010	ND	<0.010
B-7 (BH)*				
0-2	<0.010	<0.010	ND	<0.010
4-6	<0.010	<0.010	ND	<0.010
8-10	<0.010	<0.010	ND	<0.010
12-14	<0.010	<0.010	ND	<0.010
B-8 (BH)*				
0-2	<0.010	<0.010	ND	<0.010
4-6	<0.010	<0.010	ND	<0.010
8-10	<0.010	<0.010	3.6	<0.010
B-9 (BH)				
0-2	<0.010	<0.010	<0.010	<0.010
4-6	<0.010	<0.010	<0.010	<0.010
8-10	<0.010	<0.010	5.6	10.0
12-14	<0.010	<0.010	0.2	0.2

*B-3 through B-8 converted to existing monitoring wells.

Drilled by R & R International.

Analyzed by static headspace gas chromatography quantitatively for TCE and semi-quantitatively for carbon tetrachloride, chloroform, and 1,1,2,2-tetrachloroethane by SOHIO Research and Development, Warrensville Laboratory.

Table 4-2

ANALYTICAL SUMMARY:
BOREHOLE SOIL DATA
DECEMBER 1986
(ppm)

Compound	BH-1			BH-2			BH-3		
	0 - 4 Feet	4 - 8 Feet	8 - 12 Feet	0 - 4 Feet	4 - 8 Feet	8 - 12 Feet	0 - 4 Feet	4 - 8 Feet	8 - 12 Feet
Carbon tetrachloride	<0.002	<0.002	<0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Chloroform	<0.0030	0.0037	<0.002	<0.001	0.0039	0.028	0.0016	0.0016	<0.01
1,1-dichloroethane	<0.002	<0.002	<0.002	<0.001	0.0001	0.004	0.0001	0.004	<0.01
1,1-dichloroethene	<0.002	<0.002	<0.002	<0.001	<0.001	0.01	<0.004	<0.001	<0.01
Trans-1,2-dichloroethene	0.0039	0.042	<0.002	0.0011	0.076	0.24	0.0012	0.0016	<0.01
Methylene chloride	0.042	0.033	1.6	0.1	1.2	18	44	63	0.34
1,1,1-trichloroethane	<0.002	<0.002	<0.002	<0.001	<0.001	0.001	<0.001	<0.001	<0.01
Trichloroethene	0.018	0.04	0.01	0.0073	0.84	66	0.14	0.095	0.06
Vinyl chloride	<0.002	0.0023	<0.002	<0.001	<0.001	0.0015	<0.005	<0.008	<0.01

Drilled by Empire Soils Investigations.
Analyzed for volatile organics (EPA Method 8010) by RECRA Environmental.

Table 4-2 (Cont.)

Compound	BH-4				BH-5				
	0 - 4 Feet	4 - 8 Feet	8 - 12 Feet	12 - 13.3 Feet	0 - 4 Feet	4 - 8 Feet	8 - 12 Feet	12 - 16 Feet	16 - 17.3 Feet
Carbon tetrachloride	<0.002	<0.003	<0.005	<0.008	<0.002	<0.003	<0.02	<0.02	<0.02
Chloroform	<0.002	0.0038	<0.005	<0.088	<0.002	<0.003	<0.02	<0.02	<0.02
1,1-dichloroethane	<0.002	<0.003	<0.005	<0.008	<0.002	<0.003	<0.02	<0.02	<0.02
1,1-dichloroethene	<0.002	<0.003	<0.005	<0.1	<0.002	<0.1	<0.02	<0.02	<0.02
Trans-1,2-dichloroethene	<0.002	0.018	<0.014	<0.06	0.0025	0.0043	<0.02	<0.02	<0.02
Methylene chloride	0.074	6.4	0.068	3.6	3.8	12	5.7	28	11
1,1,1-trichloroethane	<0.002	0.0037	<0.005	<0.008	<0.002	<0.003	<0.02	<0.02	<0.02
Trichloroethene	0.0056	0.18	0.015	0.44	0.64	0.013	<0.02	0.12	<0.02
Vinyl chloride	<0.002	<0.003	<0.005	<0.008	0.0021	<0.003	<0.02	<0.02	<0.02

Drilled by Empire Soils Investigations.
Analyzed for volatile organics (EPA Method 8010) by RECRA Environmental.

Table 4–2 (Cont.)

Compound	BH-6 0 – 4 Feet	 4 – 8 Feet	 8 – 12 Feet	 12 – 16 Feet	 16 – 17.4 Feet	BH-7 0 – 4 Feet	 4 – 8 Feet	 8 – 12 Feet	 12 – 16 Feet
Carbon tetrachloride	<0.03	<0.02	<0.1	<0.02	<0.02	<0.02	<0.04	<0.002	<0.02
Chloroform	<0.03	0.02	<0.1	<0.02	<0.02	<0.02	<0.07	1.5	<0.02
1,1-dichloroethane	<0.03	<0.02	<0.1	<0.02	<0.02	<0.02	<0.07	<0.002	<0.02
1,1-dichloroethene	<0.03	<0.02	<0.1	<0.02	<0.05	<0.02	20.2	0.006	<0.05
Trans-1,2-dichloroethene	0.21	0.18	0.3	<0.02	0.022	<0.02	<0.063	0.63	0.03
Methylene chloride	3.4	3	34	13	14	1.7	21	4	0.67
1,1,1-trichloroethane	<0.03	<0.02	<0.1	<0.02	<0.02	<0.02	<0.039	0.013	<0.02
Trichloroethene	0.47	0.84	1.6	0.02	0.057	0.021	0.14	0.49	<0.091
Vinyl chloride	<0.03	<0.02	<0.1	<0.08	0.02	<0.02	<0.04	0.12	<0.08

Drilled by Empire Soils Investigations.
Analyzed for volatile organics (EPA Method 8010) by RECRA Environmental.

Table 4-2 (Cont.)

	BH-8				BH-9				BH-11		
Compound	0 - 4 Feet	4 - 8 Feet	8 - 12 Feet	12 - 16 Feet	0 - 4 Feet	4 - 8 Feet	8 - 12 Feet	12 - 16 Feet	0 - 4 Feet	4 - 8 Feet	8 - 12 Feet
Carbon tetrachloride	<0.02	<0.02	<0.04	<0.1	<0.02	<0.02	<0.03	<0.2	<0.02	<0.02	<0.04
Chloroform	0.33	0.05	0.11	<0.1	<0.03	<0.3	<0.03	<0.09	0.061	0.12	0.29
1,1-dichloroethane	<0.05	<0.02	<0.04	<0.1	<0.02	<0.03	<0.03	<0.2	<0.02	<0.02	<0.04
1,1-dichloroethene	<0.02	<0.02	<0.04	<0.1	<0.02	<0.03	<0.03	<0.2	<0.02	<0.02	<0.09
Trans-1,2-dichloroethene	1.9	0.45	0.075	<0.1	0.5	3.8	<0.24	0.24	<0.02	<0.02	<0.04
Methylene chloride	0.25	18	32	18	0.23	41	49	11	0.21	0.36	1.3
1,1,1-trichloroethane	<0.02	<0.02	<0.04	<0.1	<0.02	<0.036	<0.03	<0.02	<0.02	<0.02	<0.04
Trichloroethene	0.37	7.1	2.6	0.47	0.073	66	9.1	28	<0.02	0.045	0.32
Vinyl chloride	<0.02	<0.02	<0.04	<0.1	0.024	<0.02	0.036	<0.09	<0.02	<0.02	<0.04

Drilled by Empire Soils Investigations.
Analyzed for volatile organics (EPA Method 8010) by RECRA Environmental.

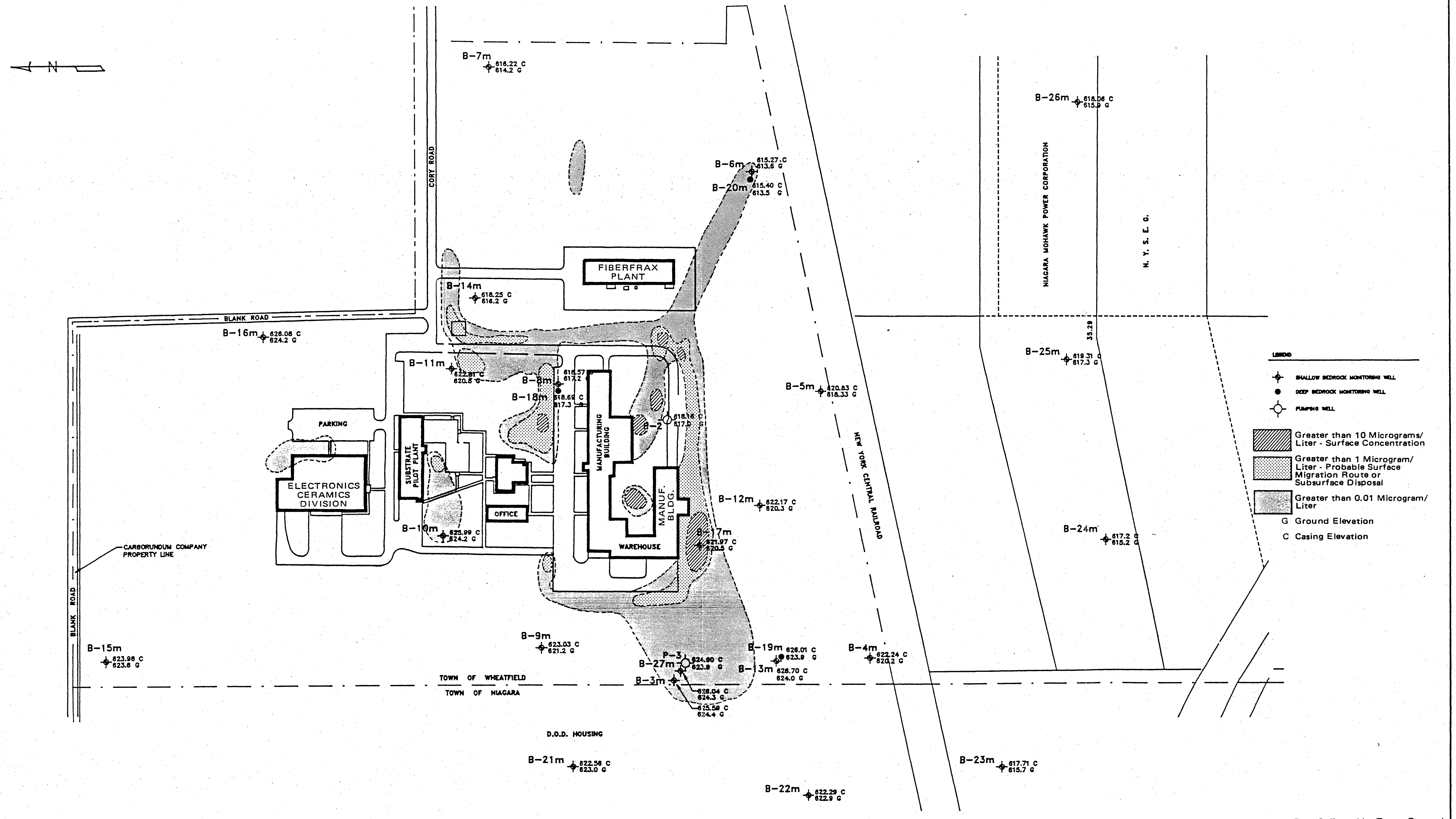
chlorinated organics found in this zone to date was 170 ppm of TCE (well B-8M) and 170 ppm of total-1,2-DCE (well B-17M) (see Table 4-3).

The deeper bedrock zones do not contain significant amounts of chlorinated organics when compared to the shallow bedrock zone. However, levels of TCE and VC in well B-19M and to a lesser extent, levels of TCE in well B-18M do exceed drinking water standards as established by the Safe Drinking Water Act and the New York State Water Quality Standards for Class GA waters. The maximum concentration detected in the deeper bedrock from the three wells installed to depths of 50 to 60 feet from the surface was 820 ppb of TCE at B-19M in April 1990. This occurs in the southwest corner of the facility area where it appears that greater hydraulic connection exists between the deeper bedrock and the shallow zones than elsewhere beneath the facility. The other two deep bedrock wells showed virtually no chlorinated organics.

4.1 SUSPECTED SOURCE AREAS

There are two focal points of very high levels of chlorinated organics on the Carborundum plant: along the southwest corner of the manufacturing building, and in the grassy area northeast of the manufacturing building. The soil gas survey (see Figure 4-1), the soil borings (see Figure 4-2), and the bedrock groundwater monitoring wells all encountered their highest levels of chlorinated organics in these two areas. Other suspected source areas include the courtyard within the manufacturing building and the area south and southeast of the manufacturing building. Past handling practices at the Carborundum facility, which were commonplace in industry during that period, suggest these areas are likely source locations of chlorinated organics. Figure 4-3 schematically outlines all the suspected source areas identified on the Carborundum plant to date.

Chlorinated organics in the overburden soils were measured on two occasions: once in 1984 during the drilling of the first soil borings [(B-1(BH) to B-9(BH)], and once in 1986 when BH-1 to BH-11 were drilled specifically as soil borings to quantify overburden source areas. The maximum detected volatile organic concentrations found in these wells are plotted in Figure 4-2. These maximum concentrations occurred in



Data Collected by Tracer Research

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Figure 4–1 INTERPRETATION OF TCE SOIL GAS CONCENTRATION MEASURED AUGUST 1986

SCALE	DATE ISSUED	C.A.D. FILE NO.	DRAWING NO.	REV.
1" = 100'		CZ2MWLOC		

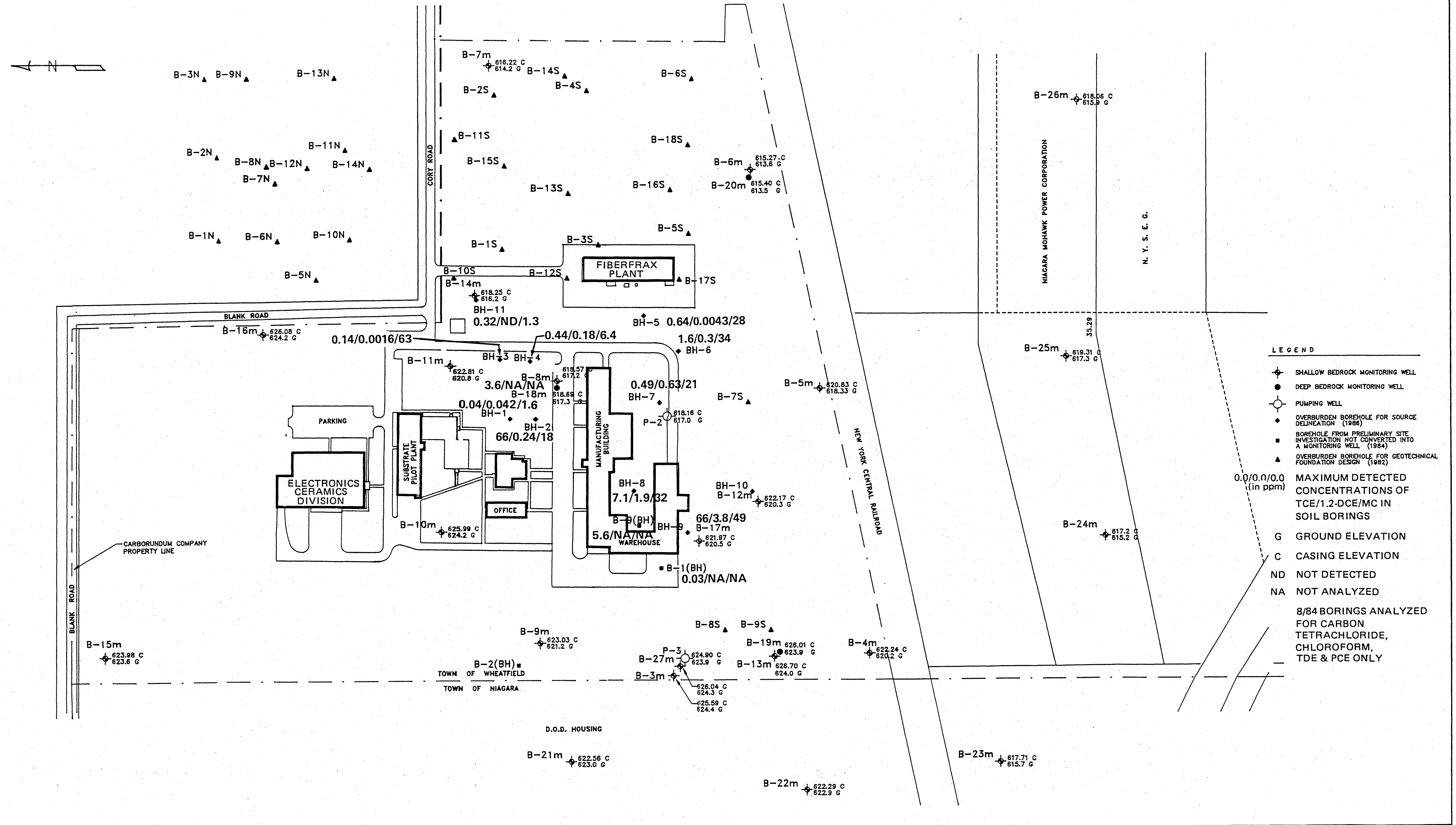

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Figure 4 - 2 MAXIMUM DETECTED CONCENTRATIONS (ppm) OF TCE/1.2 - DCE/MC FOUND IN OVERBURDEN (VARIABLE DEPTHS)

SCALE	DATE ISSUED	C.A.D. FILE NO.	DRAWING NO.	REV.
1" = 100'		CZ2MWLOC		

05-31-89 2:35 PM 9.49

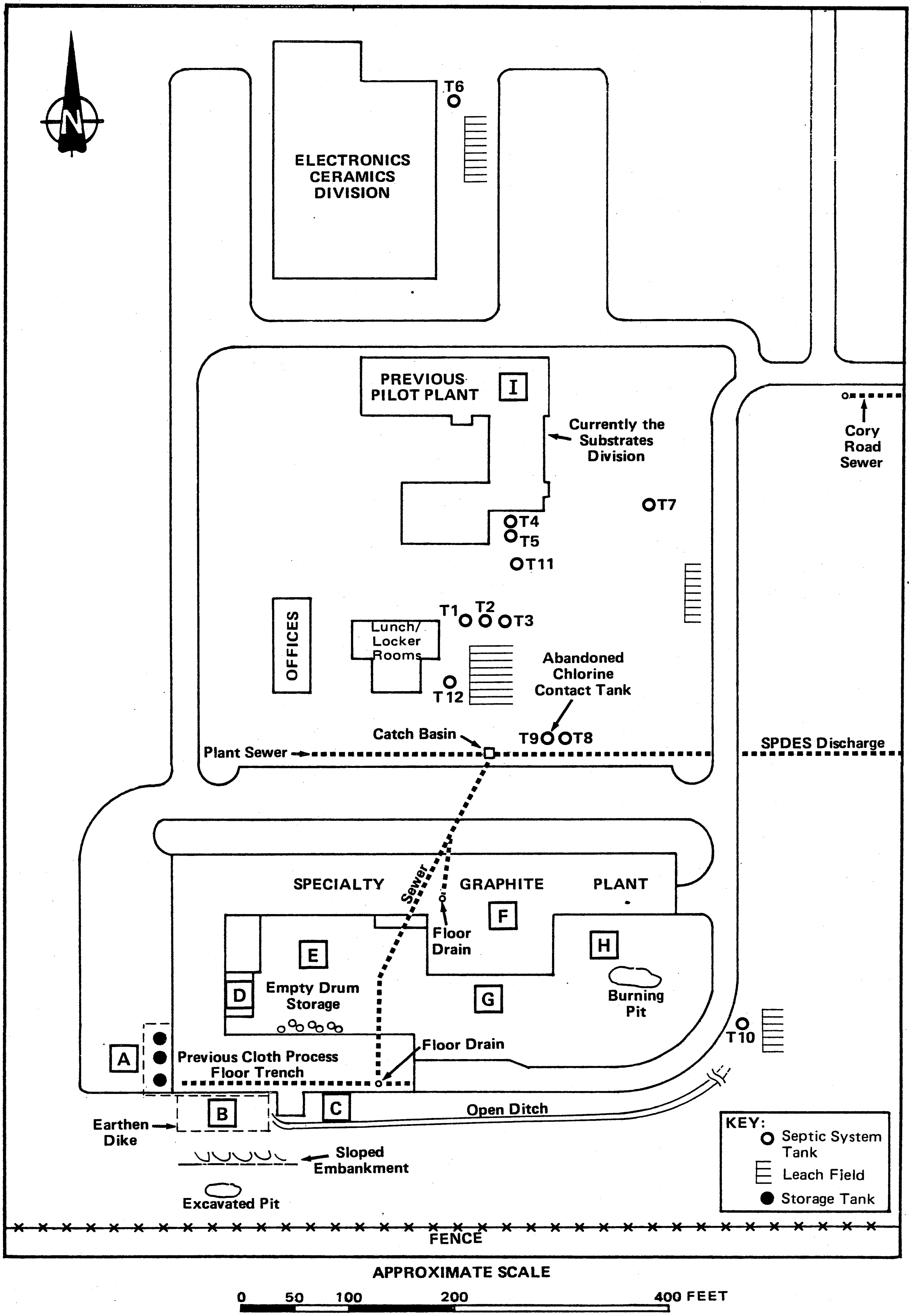


Figure 4–3 OVERBURDEN SOURCE AREAS

different depths in the various borings; however, they are most common beneath 4 feet.

Two soil gas surveys were conducted on the plant grounds in an attempt to identify probable source areas. The initial survey performed by SOHIO in 1984 was conducted as a screening technique. A more thorough survey was conducted by Tracer, Inc. in 1986. A third survey was conducted by Tracer in April and May of 1989 on the grounds of the DoD housing subdivision which borders the western plant boundary. The purpose of the third survey was to determine what potential risk, if any, soil gas vapors may pose to residents of the DoD housing subdivision. The results of the third survey are presented in Section 4.4.1.

The interpretation of these results are presented on Figure 4-1 and the complete data, as well as a full scale map of the sample points of the first two surveys, are included in Appendix C and Plate 1, respectively. These two gas surveys agree well with each other and with the results of the borehole drilling. They all identify source areas in the grassy area northeast of the manufacturing building and around the southwest corner of the manufacturing building. The drainage ditch directly to the west of the manufacturing area, the area south of the manufacturing building, and the courtyard also show concentrations above background (see Figure 4-1). Low levels of chlorinated organics were found extending out to the west of the manufacturing building in the vicinity of B-3M. Monitoring well B-3M, a shallow bedrock well, also contains high concentrations of chlorinated organics in groundwater. Only B-17M and B-8M have higher concentrations.

TCE was the major chlorinated organic used by Carborundum in their carbon and graphite cloth manufacturing process from 1963 to 1983. However, TCA was used on a one time trial basis. Carborundum shut down the cloth manufacturing facility due to market conditions in 1983. Employee interviews were conducted to acquire information about past handling practices and potential source areas. The potential source areas are depicted in Figure 4-3. The results of these interviews are summarized in the following paragraphs.

The major sources of chlorinated organics are to the south and west of the cloth manufacturing building, designated as locations A, B, and C on Figure 4-3; and in the area of the septic system tanks and the leach fields north of the manufacturing building.

Area A contained an aboveground tank farm on a concrete pad adjacent to the west wall of the building. The concrete pad was surrounded by an earthen dike. There were three tanks, one to store virgin process oil, one to store waste process oil, and one for TCE still bottoms and waste process oil. Drums of still bottoms and waste process oil were taken from the cloth building and stored in the area immediately west of the pad prior to pumping into the waste tanks. The contents of the waste tanks were periodically removed for off-site disposal. Some of the drums were periodically left open and allowed to collect precipitation, resulting in displacement of the contents from the drums. In addition, during tank loading and unloading, the residual contents of the hoses were allowed to run out onto the ground. Periodically, the crushed stone and dirt covering the drum storage area were removed and used to level the courtyard and the area immediately east of the courtyard, which are depicted as areas E and G on Figure 4-3.

Area B, where the highest levels of chlorinated organics are found in groundwater at well B-17M, contained an earthen dike which had a scrubber for oil fumes from the baking furnaces, an underground tank to store the collected water/ oil mixture from the scrubber, and an outside exhaust fan and stack connected to hoods over the top of the TCE degreasing tanks located in the cloth building. The underground tank, which was removed, was not directly used to store TCE; however, small amounts were possibly introduced from the residuals left over from the periodic cleaning of the baking furnaces with TCE. This tank was reported to have overflowed several times into the earthen dike. The oil was skimmed off the top and the water, which contained a small amount of TCE, was pumped into the excavated pit south of the earthen dike and allowed to evaporate. In the colder months, TCE was reported to condense in the stack and run down the stack wall and out of the bottom of the stack and fan. In addition, TCE still bottoms were periodically pumped out of the stills directly onto the embankment south of the earthen dike rather than placed in drums and subsequently pumped into the waste tank.

Area C also had an outside exhaust fan and stack for TCE degreasing tanks located in the building. As in Area B, condensed TCE ran out of the bottom of the stack and fan onto the ground in the winter. The open ditch between Areas B and C and continuing east past Area C allowed the transport of surface runoff containing TCE.

Area D was a covered concrete storage area utilized to store drums of virgin TCE. No releases from this area were reported.

Area E, the courtyard, was graded off with dirt and gravel containing chlorinated organics from Area A. Empty TCE drums were stored on the north courtyard wall of the cloth building. In addition, an exhaust fan and stack was located on the outside north wall of the cloth building which exhausted TCE fumes from a small yarn degreasing unit. As in Areas B and C, condensed TCE from the stack and fan ran out of the bottom during the winter.

Area F was the initial location of the cloth process prior to building the new building to the southwest. Drums of virgin TCE, waste TCE, and empty drums were stored on all three exterior sides of this location. TCE from process leaks and still bottoms was periodically discharged to the building sewer which went into the plant sewer north of the building.

Area G was a dirt and gravel storage area for drums. Dirt and gravel from Area A was also used to level Area G. Several drums of TCE or TCA were reported to have been stored there, rotted, and discharged their contents.

Area H contained an excavated burning pit that was utilized for disposal of waste process oil. Periodically during cold weather, the waste process oil was thinned with TCE to facilitate pumping of the oil from drums into the burning pit.

Area I was a pilot plant for the cloth process and utilized TCE as a degreaser. A reclaiming still was also located in this area. No further information is available on this area and the handling practices in use. TCE was suspected to be discharged to the septic tanks that were used at this time.

Within the cloth building along the south wall is a concrete trench in the floor. A drain in the east end of the trench discharged into the plant sewer system to the north. Periodically, oil on the floor was washed with small amounts of TCE and the liquids rinsed into the floor drain.

Potential sources in the grassy area north of the manufacturing building include several abandoned septic system tanks and leach fields. Very high levels of TCE have been found in monitoring well B-8M in this area (see Table 4-3). In addition to the buried septic system tanks, a central plant "catch basin" is located in this area. Waste waters, including those from the cloth building and Area F, were piped into this basin. All of the septic system tanks were sampled on two occasions. In both sampling events, TCE concentrations were found to be high. TCE in Tank 9, the abandoned chlorine contact tank, was as high as 900,000 ppb (see Table 4-4). It is likely that some of these tanks and sewers may leak slightly, resulting in the presence of very high levels of chlorinated organics in the groundwater beneath the grassy area northeast of the manufacturing building.

The southeast side of the manufacturing building is another potential source area. An abandoned septic system tanks 10E and 10W, which contains levels of TCE up to 47,000 ppb, and leach field also are located in this area. The ditch along the south side of the manufacturing building discharged into this area. Only low levels of TCE and MC have been found in the boreholes drilled in this vicinity to date.

The SPDES discharge ditch, which runs just north of the Fiberfrax plant to Cayuga Creek, and the buried sanitary sewer lines, which run along Cory Road to the Niagara County Sewer District 1 Wastewater Treatment Plant, may have also provided avenues for chlorinated organic migration. These two migration pathways will be discussed in Sections 4.4.1 and 4.4.2.

4.2 SITE-SPECIFIC GEOLOGY AND HYDROGEOLOGY

4.2.1 Geology

The near surface geology of concern beneath the Carborundum facility consists of approximately 8 to 25 feet of unconsolidated material underlain by dolomitic bedrock. The unconsolidated deposits were laid down during the Pleistocene ice age in the form of:

Table 4-3

CARBORUNDUM SPECIALTY PRODUCTS
AUGUST 1984 THROUGH APRIL 1990 SAMPLING PROGRAM COMPARISON
RESULTS REPORTED IN μg/L (ppb)

P-2

Compound	8/84	3/85	5/85	12/85	4/86	7/86	10/86	4/87	7/87	10/87	2/88	8/88
Carbon tetrachloride	ND	<5.0	<40	<2.8	<0.4	<0.4	<1.0	<0.2	<1.0	<100	<1.0	<1.0
Chloroform	8.0	<5.0	<20	<1.6	<0.2	<0.2	1.5	<0.2	<0.6	90	<1.0	8.0
1,1-dichloroethane	46	<5.0	<40	<4.7	<0.4	1.2	<1.0	<0.2	4.9	1200	<1.0	11
1,1-dichloroethene	3.0	<10	<100	<2.8	<0.4	<0.4	<1.0	<0.2	<0.4	67	<2.0	<1.0
Methylene chloride	9.0	<5.0	<20	6.4	<0.2	<0.2	<3.0	<0.2	<0.2	42	<1.0	<1.0
Trans-1,2-dichloroethene	--	--	--	--	--	--	--	--	--	--	--	--
Cis-1,2-dichloroethene	--	--	--	--	--	--	--	--	--	--	--	--
Total-1,2-dichloroethene	52	24	<60	3.4	6.2	97	12	4.8	54	3600	32	39
1,1,1-trichloroethane	320	<5.0	<60	<3.8	<0.2	0.4	<1.0	<0.2	29	3700	<1.0	7.0
Trichloroethene	340	81	58	57	32	300	180	21	490	19000	110	82
Vinyl chloride	7.0	<5.0	<40	<10	<0.4	0.6	<1.0	<0.2	<1.3	150	<2.0	<2.0
Tetrachloroethene	--	--	--	--	--	--	--	--	--	--	--	--

Key at end of table.

Table 4-3 (Cont.)

P-2

Compound	11/88	1/89	4/89	7/89	10/89	1/90	4/90
Carbon tetrachloride	<0.2	<0.1	26	<1.2	<1.0	<5.0	<1.0
Chloroform	<0.2	R	<0.05	<0.5	<0.5	<2.5	<0.5
1,1-dichloroethane	2.0	2.6	<0.07	<0.7	110	<3.5	<0.7
1,1-dichloroethene	0.2	0.4	<0.03	<1.3	6.7	<5.0	<1.0
Methylene chloride	0.7	<0.1	<0.1	<2.5	<1.0	<25	<5.0
Trans-1,2-dichloroethene	--	2.4	<0.1	<1.0	1.9	<5.0	<1.0
Cis-1,2-dichloroethene	--	48	5.0	12	140	21	3.9
Total-1,2-dichloroethene	190	50	5.0	12	150	21	3.9
1,1,1-trichloroethane	3.6	9.5	<0.03	<0.3	240	<1.5	<0.3
Trichloroethene	1600	560	<0.1	93	1200	190	30
Vinyl chloride	7.6	1.4	<0.2	<1.8	19	<5.0	<1.0
Tetrachloroethene	--	0.3	<0.03	<0.3	<0.3	<1.5	<0.3

Key at end of table.

Table 4-3 (Cont.)

	P-3							
Compound	11/88	12/88	1/89	4/89	7/89	10/89	1/90	4/90
Carbon tetrachloride	<1.0	<0.4	<0.1	<0.1	<1.2	<1.0	<1.0	<1.0
Chloroform	<1.0	<0.4	R	<0.05	<0.5	<0.5	<0.5	<0.5
1,1-dichloroethane	<1.0	<0.4	<0.07	<0.07	<0.7	<0.7	<0.7	<0.7
1,1-dichloroethene	<1.0	<0.8	<0.1	<0.03	<1.3	<1.0	<1.0	<1.0
Methylene chloride	1.4	2.5	<0.1	<0.1	<2.5	<1.0	<5.0	<5.0
Trans-1,2-dichloroethene	--	--	<0.1	<0.1	<1.0	<1.0	<1.0	<1.0
Cis-1,2-dichloroethene	--	--	<1.0	<1.0	<1.0	40	2.1	<1.0
Total-1,2-dichloroethene	21	4.3	<1.0	<1.0	<1.0	40	2.1	<1.0
1,1,1-trichloroethane	<1.0	<0.4	0.5	<0.03	<0.3	<0.3	<0.3	<0.3
Trichloroethene	<1.0	0.6	<0.1	<0.1	<1.2	<1.0	<1.0	<1.0
Vinyl chloride	<1.0	<2.0	<0.2	<0.2	<1.8	6.5	<1.0	<1.0
Tetrachloroethene	--	--	<0.03	<0.03	<0.3	<0.3	<0.3	<0.3

Key at end of table.

Table 4-3 (Cont.)

B-3M

Compound	8/84	3/85	5/85	12/85	4/86	7/86	10/86	1/87	4/87	7/87	10/87	2/88	8/88
Carbon tetrachloride	ND	<2000	<500	<28	<200	<50	<30	<2.0	<20	<20	<20	<20	<20
Chloroform	ND	<1000	<300	<16	<100	<50	<30	<100	<100	<200	<400	<500	<20
1,1-dichloroethane	8.0	<1000	<500	88	220	190	190	12	70	240	78	310	<20
1,1-dichloroethene	16	<5000	<1000	74	140	75	140	19	70	<40	85	230	<20
Methylene chloride	ND	<1000	<300	<28	<100	<50	<60	<2.0	<20	<20	<10	<20	<20
Trans-1,2-dichloroethene	—	—	—	—	—	—	—	—	—	—	—	—	—
Cis-1,2-dichloroethene	—	—	—	—	—	—	—	—	—	—	—	—	—
Total-1,2-dichloroethene	250	110000	48000	13000	52000	14000	24000	6700	32000	8600	12000	41000	9700
1,1,1-trichloroethane	16	<3000	1100	160	400	170	170	45	140	570	230	450	<20
Trichloroethene	110	24000	7900	7800	5500	340	4400	260	120	3500	920	1200	<20
Vinyl chloride	79	<2000	1300	490	1400	1700	2400	270	1400	880	1900	2600	1600
Tetrachloroethene	—	—	—	—	—	—	—	—	—	—	—	—	—

Key at end of table.

Table 4-3 (Cont.) B-3M

Compound	11/88	1/89	4/89	7/89	10/89	1/90	4/90
Carbon tetrachloride	<1.0	<50	<1.2	<100	<100	<100	<25
Chloroform	<100	R	<0.5	<50	<50	<50	<13
1,1-dichloroethane	70	<35	250	170	59	270	23
1,1-dichloroethene	39	<65	220	110	64	250	<25
Methylene chloride	1.5	<50	<1.0	<100	<100	<500	<125
Trans-1,2-dichloroethene	--	55	75	81	68	150	<25
Cis-1,2-dichloroethene	--	15000	17000	17000	8300	34000	4300
Total-1,2-dichloroethene	17000	15000	17000	17000	8300	34000	4300
1,1,1-trichloroethane	87	<15	<0.3	170	<30	230	<7.5
Trichloroethene	140	<200	6800	940	140	5700	<25
Vinyl chloride	3200	1200	2400	4000	2200	3500	370
Tetrachloroethene	--	<15	<0.3	<30	<30	<30	<7.5

Key at end of table.

Table 4-3 (Cont.)

B-4M

Compound	8/84	3/85	5/85	12/85	4/86	7/86	10/86	1/87	4/87	7/87	10/87	2/88	8/88
Carbon tetrachloride	ND	<50	<20	<2.8	<20	<2.0	<10	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Chloroform	8.0	<50	<10	<1.6	<10	<2.0	<50	<5.0	<1.0	<30	<5.0	<20	<1.0
1,1-dichloroethane	ND	<50	<20	6.6	<20	6.2	<10	2.3	5.7	1.7	4.2	7.6	<1.0
1,1-dichloroethene	ND	<200	<50	4.2	<20	<2.0	<20	5.0	6.9	<2.0	<1.0	2.9	<1.0
Methylene chloride	ND	<50	<30	5.6	15	<2.0	<20	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Trans-1,2-dichloroethene	--	--	--	--	--	--	--	--	--	--	--	--	--
Cis-1,2-dichloroethene	--	--	--	--	--	--	--	--	--	--	--	--	--
Total-1,2-dichloroethene	10	4500	340	1100	3000	390	650	690	1400	700	550	1300	360
1,1,1-trichloroethane	ND	<80	<30	<3.8	18	<2.0	<70	2.6	1.3	<1.0	<1.0	<1.0	<1.0
Trichloroethene	14	670	180	560	990	73	170	310	580	21	48	410	4.0
Vinyl chloride	ND	<70	<70	17	39	18	<30	48	75	5.6	11	29	<2.0
Tetrachloroethene	--	--	--	--	--	--	--	--	--	--	--	--	--

Key at end of table.

Table 4-3 (Cont.)

B-4M

Compound	11/88	1/89	4/89	7/89	10/89	1/90	4/90
Carbon tetrachloride	<1.0	<0.1	<0.1	<1.2	<1.0	<10	<1.0
Chloroform	<1.0	R	<0.05	<0.5	<0.5	<5.0	<0.5
1,1-dichloroethane	<1.0	2.5	7.3	4.1	<0.7	5.3	3.5
1,1-dichloroethene	<1.0	1.3	7.5	3.4	3.9	<10	<1.0
Methylene chloride	<1.0	0.3	<0.1	<2.5	<1.0	<50	<5.0
Trans-1,2-dichloroethene	--	8.6	14	7.6	10	18	7.9
Cis-1,2-dichloroethene	--	200	450	380	410	440	570
Total-1,2-dichloroethene	95	210	460	380	420	450	580
1,1,1-trichloroethane	<1.0	<0.03	<0.03	<0.3	8.8	<3.0	<0.3
Trichloroethene	21	57	220	120	12	130	130
Vinyl chloride	<1.0	37	49	54	18	51	26
Tetrachloroethene	--	<0.03	<0.03	<0.3	<0.3	<3.0	<0.3

Key at end of table.

Table 4-3 (Cont.)

B-5M

Compound	8/84	3/85	5/85	12/85	4/86	1/87	4/87	7/87	10/87	2/88	8/88
Carbon tetrachloride	ND	<5.0	<4.0	<2.8	<0.4	<0.2	<0.2	<0.2	<0.2	<0.2	<1.0
Chloroform	ND	<5.0	<2.0	<1.6	<0.2	<0.4	<0.2	<0.6	<0.4	<1.0	<1.0
1,1-dichloroethane	ND	<5.0	<4.0	<4.7	0.7	0.3	<0.2	<0.4	<0.2	0.6	<1.0
1,1-dichloroethene	ND	<10	<10	<3.8	<0.4	<0.2	<0.2	<0.4	<0.2	<0.4	<1.0
Methylene chloride	ND	<5.0	<2.0	8.4	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<1.0
Trans-1,2-dichloroethene	--	--	--	--	--	--	--	--	--	--	--
Cis-1,2-dichloroethene	--	--	--	--	--	--	--	--	--	--	--
Total-1,2-dichloroethene	69	53	19	31	20	35	13	27	28	39	24
1,1,1-trichloroethane	ND	<5.0	<6.0	<3.8	<0.4	<0.2	<0.2	<0.2	<0.2	<0.2	<1.0
Trichloroethene	270	14	7.9	30	5.4	20	7.3	8.3	9.4	33	28
Vinyl chloride	8.0	<5.0	<5.0	10	1.0	3.7	<0.2	1.2	2.1	3.5	<2.0
Tetrachloroethene	--	--	--	--	--	--	--	--	--	--	--

Key at end of table.

Table 4-3 (Cont.)

B-5M

Compound	11/88	1/89	4/89	7/89	10/89	1/90	4/90
Carbon tetrachloride	<0.2	<0.1	<0.1	<1.2	<1.0	<1.0	<1.0
Chloroform	<0.2	R	<0.05	<0.5	<0.5	<0.5	<0.5
1,1-dichloroethane	0.9	0.2	1.6	<0.7	1.5	3.3	3.0
1,1-dichloroethene	<0.2	<0.1	0.5	<1.3	<1.0	<1.0	<1.0
Methylene chloride	<1.0	<0.1	<0.1	<2.5	<1.0	<5.0	<5.0
Trans-1,2-dichloroethene	--	0.3	0.4	<1.0	<1.0	<1.0	<1.0
Cis-1,2-dichloroethene	--	11	15	6.2	15	31	14
Total-1,2-dichloroethene	23	11	15	6.2	15	31	14
1,1,1-trichloroethane	<0.2	0.8	<0.03	<0.3	4.3	9.6	4.6
Trichloroethene	38	9.2	140	77	130	410	150
Vinyl chloride	2.6	3.2	1.8	<1.8	3.1	1.9	<1.0
tetrachloroethene	--	<0.03	<0.03	<0.3	<0.3	<0.3	<0.3

Key at end of table.

Table 4-3 (Cont.)

B-6M

Compound	8/84	3/85	5/85	12/85	4/86	7/86	10/86	1/87	4/87	7/87	10/87	2/88	8/88
Carbon tetrachloride	ND	<5.0	<2.0	<2.8	<0.4	<0.4	<0.4	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Chloroform	14	<5.0	<1.0	<1.6	<0.2	<0.4	<0.4	<0.4	<0.2	<0.6	<0.2	<0.8	<0.2
1,1-dichloroethane	ND	<5.0	<2.0	<4.7	<0.4	<0.4	<0.4	<0.2	<0.2	<0.4	<0.2	<0.2	<0.2
1,1-dichloroethene	ND	<10	<5.0	<2.8	<0.4	<0.4	<0.4	<0.2	<0.2	<0.4	<0.2	<0.4	<0.2
Methylene chloride	2.0	<5.0	<1.0	7.6	<0.2	<0.4	<0.4	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Trans-1,2-dichloroethene	--	--	--	--	--	--	--	--	--	--	--	--	--
Cis-1,2-dichloroethene	--	--	--	--	--	--	--	--	--	--	--	--	--
Total-1,2-dichloroethene	ND	41	9.4	17	12	8.4	23	32	1.8	25	3.1	43	25
1,1,1-trichloroethane	ND	<5.0	<3.0	<3.8	0.2	<0.4	<0.4	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Trichloroethene	2.0	41	31	49	38	25	97	86	2.8	50	7.9	180	120
Vinyl chloride	ND	<5.0	<2.0	<10	0.8	1.4	3.6	3.2	<0.2	1.4	<0.4	3.9	5.0
Tetrachloroethene	--	--	--	--	--	--	--	--	--	--	--	--	--

Key at end of table.

Table 4-3 (Cont.)

B-6M

Compound	11/88	1/89	4/89	7/89	10/89	1/90	4/90
Carbon tetrachloride	<0.2	<0.1	<0.1	<1.2	<1.0	<1.0	<1.0
Chloroform	<0.2	R	<0.05	0.7	<0.5	<0.5	<0.5
1,1-dichloroethane	<0.2	<0.07	<0.07	<0.7	<0.7	<0.7	<0.7
1,1-dichloroethene	<0.2	<0.1	<0.03	<1.3	<1.0	<1.0	<1.0
Methylene chloride	<1.0	<0.1	<0.1	<2.5	<1.0	<5.0	<5.0
Trans-1,2-dichloroethene	--	0.6	<0.1	<1.0	<1.0	<1.0	<1.0
Cis-1,2-dichloroethene	--	11	2.0	1.7	4.3	24	9.1
Total-1,2-dichloroethene	64	12	2.0	1.7	4.3	24	9.1
1,1,1-trichloroethane	<0.2	<0.03	<0.03	<0.3	<0.3	<0.3	<0.3
Trichloroethene	120	99	15	18	40	260	88
Vinyl chloride	2.6	5.3	<0.2	6.6	1.2	7.1	<1.0
Tetrachloroethene	--	<0.03	<0.03	<0.3	<0.3	<0.3	<0.3

Key at end of table.

Table 4-3 (Cont.)

B-7M

Compound	8/84	3/85	5/85	12/85	4/86	7/86	10/86	1/87	4/87	7/87	10/87	2/88	8/88
Carbon tetrachloride	ND	<2.0	<1.0	<2.8	<0.4	<0.4	<0.4	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Chloroform	3.0	<2.0	<1.0	<1.6	<0.2	<0.2	<0.4	<0.4	<0.2	<0.2	<0.2	<0.2	<0.2
1,1-dichloroethane	ND	<2.0	<1.0	<4.7	<0.4	<0.2	<0.4	<0.2	<0.2	<0.4	<0.2	<0.2	<0.2
1,1-dichloroethene	ND	<2.0	<1.0	<2.8	<0.4	<0.4	<0.4	<0.2	<0.2	<0.4	<0.2	<0.2	<0.2
Methylene chloride	1.0	<2.0	<1.0	5.4	<0.2	<0.2	<0.4	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Trans-1,2-dichloroethene	--	--	--	--	--	--	--	--	--	--	--	--	--
Cis-1,2-dichloroethene	--	--	--	--	--	--	--	--	--	--	--	--	--
Total-1,2-dichloroethene	ND	<2.0	<1.0	<1.6	0.5	1.3	0.9	1.9	1.3	1.0	1.6	1.4	2.0
1,1,1-trichloroethane	ND	<2.0	<1.0	<3.8	<0.2	<0.2	<0.4	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Trichloroethene	7.0	<2.0	<1.0	6.8	2.6	1.1	0.4	9.6	3.9	1.5	<0.2	20	29
Vinyl chloride	ND	<2.0	<1.0	<10	<0.4	<0.4	<0.4	<0.2	<0.2	<0.6	<0.4	<0.2	<0.4
Tetrachloroethene	--	--	--	--	--	--	--	--	--	--	--	--	--

Key at end of table.

Table 4-3 (Cont.)

B-7M

Compound	11/88	1/89	4/89	7/89	10/89	1/90	4/90
Carbon tetrachloride	11	<0.1	<0.1	<1.2	5.7	<1.0	<1.0
Chloroform	<0.2	R	<0.05	0.7	<0.5	1.0	<0.5
1,1-dichloroethane	<0.2	<0.07	<0.07	<0.7	<0.7	<0.7	<0.7
1,1-dichloroethene	<0.2	<0.1	<0.03	<1.3	<1.0	<1.0	<1.0
Methylene chloride	<0.2	<0.1	<0.1	<2.5	<1.0	<5.0	<5.0
Trans-1,2-dichloroethene	--	<0.1	<0.1	<1.0	<1.0	<1.0	<1.0
Cis-1,2-dichloroethene	--	1.0	31	1.4	2.2	6.4	9.5
Total-1,2-dichloroethene	2.8	1.0	31	1.4	2.2	6.4	9.5
1,1,1-trichloroethane	<0.2	<0.03	<0.03	<0.3	<0.3	<0.3	<0.3
Trichloroethene	<0.2	9.0	7.3	22	35	200	28
Vinyl chloride	<0.2	<0.2	<0.2	<1.8	<1.0	<1.0	<1.0
Tetrachloroethene	--	<0.03	<0.03	<0.3	<0.3	<0.3	<0.3

Key at end of table.

Table 4-3 (Cont.)

B-8M

Compound	8/84	3/85	5/85	12/85	4/86	7/86	10/86	4/87	7/87	10/87	2/88	8/88
Carbon tetrachloride	2.0	<2000	<400	<1400	<200	<200	<100	<1.0	<20	<1.0	<200	<100
Chloroform	10	<1000	<200	<800	<100	<100	180	38	<20	<5.0	<200	<100
1,1-dichloroethane	7.0	<1000	<400	<2400	<200	<200	<100	8.5	<40	2.7	<200	<100
1,1-dichloroethene	6.0	<4000	<1000	<1400	<200	<200	<100	7.6	<40	<1.0	<200	<100
Methylene chloride	2.0	1700	<200	<1400	<200	<100	<200	<1.0	<20	<1.0	<200	<100
Trans-1,2-dichloroethene	--	--	--	--	--	--	--	--	--	--	--	--
Cis-1,2-dichloroethene	--	--	--	--	--	--	--	--	--	--	--	--
Total-1,2-dichloroethene	390	14000	1400	<800	730	1900	<100	680	530	270	4200	1300
1,1,1-trichloroethane	ND	<2000	<600	<1900	<100	<200	<100	11	<20	1.8	<200	<100
Trichloroethene	40000	84000	39000	98000	72000	16000	62000	22000	16000	11000	170000	51000
Vinyl chloride	57	<2000	<400	<5000	<200	<200	<200	230	<60	8.1	<400	<200
Tetrachloroethene	--	--	--	--	--	--	--	--	--	--	--	--

Key at end of table.

Table 4-3 (Cont.)

B-8M

Compound	11/88	1/89	4/89	7/89	10/89	1/90	4/90
Carbon tetrachloride	6.0	<0.1	460	<1000	<1000	<1000	<1000
Chloroform	19	R	110	<500	<500	520	<500
1,1-dichloroethane	6.0	<0.07	<7.0	<700	<700	<700	<700
1,1-dichloroethene	8.0	<0.1	<3.0	<1000	<1000	<1000	<1000
Methylene chloride	<1.0	<0.1	<10	<1000	<1000	<5000	<5000
Trans-1,2-dichloroethene	--	<0.1	<10	<1000	<1000	<1000	<1000
Cis-1,2-dichloroethene	--	90	480	650	<1000	1600	<1000
Total-1,2-dichloroethene	37	90	490	650	<1000	1600	<1000
1,1,1-trichloroethane	8.0	<0.03	<3.0	<300	<300	<300	<300
Trichloroethene	49000	7500	81000	46000	18000	100000	47000
Vinyl chloride	67	22	<18	<1000	<1000	<1000	<1000
Tetrachloroethene	--	<0.03	<0.03	<300	<300	<300	<300

Key at end of table.

Table 4-3 (Cont.)

B-9M

Compound	1/87	4/87	7/87	10/87	2/88	8/88	1/89	4/89	7/89	10/89	1/90	4/90
Carbon tetrachloride	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.1	<0.1	<1.2	<1.0	<1.0	<1.0
Chloroform	0.8	<0.2	<0.2	<0.2	<0.2	<0.2	R	<0.05	<0.5	<0.5	<0.5	<0.5
1,1-dichloroethane	<0.2	<0.2	<0.4	<0.2	<0.2	<0.2	<0.07	0.3	<0.7	<0.7	<0.7	<0.7
1,1-dichloroethene	<0.2	<0.2	<0.4	<0.2	<0.2	<0.2	<0.1	<0.03	<1.3	<1.0	<1.0	<1.0
Methylene chloride	<0.2	1.3	<0.2	<0.2	<0.2	<0.2	<0.1	<0.1	<2.5	<1.0	<5.0	<5.0
Trans-1,2-dichloroethene	--	--	--	--	--	--	<0.1	<0.1	<1.0	<1.0	<1.0	<1.0
Cis-1,2-dichloroethene	--	--	--	--	--	--	<1.0	11	<1.0	<1.0	<1.0	<1.0
Total-1,2-dichloroethene	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<1.0	11	<1.0	<1.0	<1.0	<1.0
1,1,1-trichloroethane	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.03	<0.03	<0.3	<1.3	<0.3	<0.3
Trichloroethene	0.4	<0.2	<0.2	<0.2	<0.2	<0.2	2.4	20	<1.2	<1.0	<1.0	<1.0
Vinyl chloride	3.6	<0.2	<0.6	<0.4	<0.2	<0.4	<0.2	1.3	<1.8	<1.0	<1.0	<1.0
Tetrachloroethene	--	--	--	--	--	--	0.1	0.3	<0.3	1.6	0.4	<0.3

Key at end of table.

Table 4-3 (Cont.)

B-10M

Compound	1/87	4/87	7/87	10/87	2/88	8/88	11/88	1/89	4/89	7/89	10/89	1/90	4/90
Carbon tetrachloride	<0.2	<0.2	<0.6	<0.8	<0.2	<0.2	<1.0	<0.1	<0.1	<1.2	<1.0	<5.0	<5.0
Chloroform	<0.4	<0.2	<2.0	<1.0	<0.2	<0.2	<1.0	R	<0.05	<0.5	<0.5	<2.5	<2.5
1,1-dichloroethane	0.4	0.7	2.7	1.3	2.5	5.2	4.0	0.8	1.5	<1.1	1.7	<3.5	<3.5
1,1-dichloroethene	0.2	0.5	1.8	0.8	0.6	<0.2	<1.0	0.4	1.6	<1.3	1.4	<5.0	<5.0
Methylene chloride	<0.2	<0.2	<0.2	<0.2	0.2	<0.2	<1.0	<0.1	<0.1	<2.5	<1.0	<25	<25
Trans-1,2-dichloroethene	--	--	--	--	--	--	--	0.9	0.6	1.0	5.2	<5.0	<5.0
Cis-1,2-dichloroethene	--	--	--	--	--	--	--	18	29	46	48	53	22
Total-1,2-dichloroethene	24	50	170	53	18	190	160	19	30	47	53	53	22
1,1,1-trichloroethane	2.5	7.8	13	6.2	12	22	17	8.9	<0.03	7.2	10	12	2.8
Trichloroethene	48	83	240	80	32	160	70	5.2	110	150	81	150	75
Vinyl chloride	0.8	<0.2	<0.6	<0.4	<0.2	<0.4	<1.0	0.2	<0.2	<1.8	<1.0	<5.0	<5.0
Tetrachloroethene	--	--	--	--	--	--	--	0.03	<0.03	<0.3	<0.3	<1.5	<1.5

Key at end of table.

Table 4-3 (Cont.)

B-11M

Compound	1/87	4/87	7/87	10/87	2/88	8/88	11/88	1/89	4/89	7/89	10/89	1/90	4/90
Carbon tetrachloride	<0.2	<0.2	<0.4	<1.0	<1.0	<1.0	<1.0	<0.1	<0.1	<1.2	<10	<1.0	<1.0
Chloroform	<0.4	<0.2	<20	<4.0	<1.0	<1.0	<1.0	R	<0.05	1.1	<5.0	2.2	<0.5
1,1-dichloroethane	<0.2	<0.2	<0.4	<1.0	<1.0	<1.0	<1.0	<0.07	<0.07	<0.7	<7.0	<0.7	<0.7
1,1-dichloroethene	<0.2	<0.2	1.3	<1.0	<1.0	<1.0	<1.0	<0.1	<0.03	<1.3	<10	<1.0	<1.0
Methylene chloride	<0.2	<0.2	<0.2	<1.0	<6.0	<1.0	<1.0	<0.1	<0.1	<2.5	<10	8.0	<5.0
Trans-1,2-dichloroethene	--	--	--	--	--	--	--	0.6	<0.1	<1.0	5.4	1.8	<1.0
Cis-1,2-dichloroethene	--	--	--	--	--	--	--	23	9.0	9.9	80	23	11
Total-1,2-dichloroethene	26	39	310	150	120	350	110	24	9.0	9.9	85	25	11
1,1,1-trichloroethane	0.2	<0.2	2.2	<1.0	<1.0	<1.0	<1.0	<0.03	<0.03	<0.3	<3.0	<0.3	<0.3
Trichloroethene	440	170	2100	4500	650	1200	1900	540	520	290	1600	360	130
Vinyl chloride	<0.2	<0.2	<0.6	<2.0	<1.0	<2.0	<1.0	<0.2	<0.2	<1.8	<10	<1.0	<1.0
Tetrachloroethene	--	--	--	--	--	--	--	9.9	3.3	3.1	20	6.6	3.3

Key at end of table.

Table 4-3 (Cont.)

B-12M

Compound	1/87	4/87	7/87	10/87	2/88	8/88	11/88	1/89	4/89	7/89	10/89	1/90	4/90
Carbon tetrachloride	<0.4	<0.2	<20	<20	<1.0	<1.0	<10	<1.2	<0.1	<1.2	<25	<25	<5.0
Chloroform	<2.0	<0.2	<400	<50	<4.0	<1.0	<10	R	<0.05	<0.5	<13	<13	<2.5
1,1-dichloroethane	11	7.0	250	120	15	46	120	49	7.4	21	160	38	25
1,1-dichloroethene	0.8	<0.2	<40	10	<2.0	<1.0	38	7.0	1.5	<1.3	23	<25	<5.0
Methylene chloride	<0.2	<0.2	61	<10	<1.0	<1.0	<10	0.8	<0.1	<2.5	<25	<130	<25
Trans-1,2-dichloroethene	--	--	--	--	--	--	--	23	1.4	<1.0	14	<25	<5.0
Cis-1,2-dichloroethene	--	--	--	--	--	--	--	700	40	370	1000	440	240
Total-1,2-dichloroethene	95	91	11000	1600	280	390	6600	720	41	370	1100	440	240
1,1,1-trichloroethane	13	7.8	490	140	20	56	270	80	<0.03	<0.3	230	31	26
Trichloroethene	180	130	10000	9900	890	840	2200	870	150	570	2500	890	410
Vinyl chloride	4.8	<0.2	62	44	13	76	1400	28	<0.2	55	100	<25	<5.0
Tetrachloroethene	--	--	--	--	--	--	--	<0.3	<0.03	<0.3	<7.5	<7.5	<1.5

Key at end of table.

Table 4-3 (Cont.)

B-13M

Compound	1/87	4/87	7/87	10/87	2/88	8/88	11/88	4/89	7/89	10/89	1/90	4/90
Carbon tetrachloride	<2.0	<1.0	<4.0	<5.0	<4.0	<4.0	<20	<0.1	<10	<50	<50	<25
Chloroform	<40	<40	<100	<200	<200	<4.0	<40	<0.05	<5.0	<25	<25	<13
1,1-dichloroethane	5.2	21	33	27	62	970	110	19	50	62	59	33
1,1-dichloroethene	2.8	20	25	14	36	39	63	13	31	57	62	<25
Methylene chloride	<1.0	960	<2.0	<1.0	<4.0	<4.0	47	<0.1	<10	<50	<250	<130
Trans-1,2-dichloroethene	--	--	--	--	--	--	--	9.1	31	47	59	<25
Cis-1,2-dichloroethene	--	--	--	--	--	--	--	1800	6300	7700	7800	4700
Total-1,2-dichloroethene	1800	5000	4600	6900	8800	14000	21000	1800	6300	7800	7900	4700
1,1,1-trichloroethane	8.0	28	37	37	39	48	79	<0.03	<3.0	<15	<15	<7.5
Trichloroethene	160	640	280	650	570	670	910	210	430	500	450	150
Vinyl chloride	54	840	270	200	510	1100	1400	170	730	730	500	370
Tetrachloroethene	--	--	--	--	--	--	--	<0.03	<3.0	<15	<15	<7.5

Key at end of table.

Table 4-3 (Cont.)

	B-14M										
Compound	4/87	7/87	10/87	2/88	8/88	1/89	4/89	7/89	10/89	1/90	4/90
Carbon tetrachloride	<0.2	<4.0	<4.0	<4.0	<4.0	<0.1	<0.6	<1.2	<25	<5.0	<25
Chloroform	<0.2	<5.0	<8.0	<4.0	<4.0	R	400	<0.5	<13	<2.5	<13
1,1-dichloroethane	<0.2	<8.0	<4.0	<4.0	<4.0	0.08	<0.4	<0.7	<18	<3.5	<18
1,1-dichloroethene	<0.2	<8.0	<4.0	<4.0	<4.0	0.6	<0.2	<1.3	<25	<5.0	<25
Methylene chloride	<0.2	<4.0	<4.0	<4.0	<4.0	<0.1	<0.5	<2.5	<25	<25	<130
Trans-1,2-dichloroethene	--	--	--	--	--	2.2	<0.5	<1.0	<25	<5.0	<25
Cis-1,2-dichloroethene	--	--	--	--	--	46	15	19	120	70	<25
Total-1,2-dichloroethene	4.0	160	110	64	<4.0	48	15	19	120	70	<25
1,1,1-trichloroethane	<0.2	<4.0	<4.0	<4.0	<4.0	1.1	<0.2	<1.3	<7.5	<1.5	<7.5
Trichloroethene	130	7700	6600	2400	5300	2900	1300	500	7500	1500	75
Vinyl chloride	<0.2	<10	<8.0	19	<8.0	0.2	<0.9	<1.8	<25	<5.0	<25
Tetrachloroethene	--	--	--	--	--	<0.03	<0.2	<0.3	<7.5	2.1	<7.5

Key at end of table.

Table 4-3 (Cont.)

B-15M

Compound	2/88	8/88	11/88	1/89	4/89	7/89	10/89	1/90	4/90
Carbon tetrachloride	<0.2	<0.2	<0.2	<0.1	<0.1	<1.2	<1.0	<1.0	<1.0
Chloroform	<0.2	<0.2	<0.2	R	<0.05	0.5	<0.5	<0.5	<0.5
1,1-dichloroethane	<0.2	<0.2	<0.2	<0.07	<0.07	<0.7	<0.7	<0.7	<0.7
1,1-dichloroethene	<0.2	<0.2	<0.2	<0.1	<0.03	<1.3	<1.0	<1.0	<1.0
Methylene chloride	<0.2	<0.2	<1.0	<0.1	<0.1	<2.5	<1.0	<5.0	<5.0
Trans-1,2-dichloroethene	--	--	--	<0.1	<0.1	<1.0	<1.0	<1.0	<1.0
Cis-1,2-dichloroethene	--	--	--	1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Total-1,2-dichloroethene	<0.2	<0.2	<0.2	1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1,1-trichloroethane	<0.2	<0.2	<0.2	<0.03	<0.03	1.2	<0.3	<0.3	<0.3
Trichloroethene	<0.2	<0.2	9.0	5.8	0.4	<1.2	<1.0	<1.0	<1.0
Vinyl chloride	<0.2	<0.4	<0.2	<0.2	<0.2	<1.8	<1.0	<1.0	<1.0
Tetrachloroethene	--	--	--	<0.03	<0.03	<0.3	<0.3	<0.3	<0.3

Key at end of table.

Table 4-3 (Cont.)

B-16M

Compound	2/88	8/88	11/88	1/89	4/89	7/89	10/89	1/90	4/90
Carbon tetrachloride	<0.2	<0.2	<0.2	<0.1	<0.1	<1.2	<1.0	<1.0	<1.0
Chloroform	<0.2	<0.2	<0.2	R	<0.05	<0.5	<0.5	0.7	<0.5
1,1-dichloroethane	<0.2	<0.2	<0.2	<0.07	<0.07	<0.7	<0.7	<0.7	<0.7
1,1-dichloroethene	<0.2	<0.2	<0.2	<0.1	<0.03	<1.3	<1.0	<1.0	<1.0
Methylene chloride	<0.2	<0.2	<1.0	<0.1	<0.1	<2.5	<1.0	<5.0	<5.0
Trans-1,2-dichloroethene	--	--	--	<0.1	<0.1	<1.0	<1.0	<1.0	<1.0
Cis-1,2-dichloroethene	--	--	--	<1.0	<1.0	<1.0	<1.0	<1.0	3.0
Total-1,2-dichloroethene	<0.2	3.0	<0.2	<1.0	<1.0	<1.0	<1.0	<1.0	3.0
1,1,1-trichloroethane	<0.2	<0.2	<0.2	<0.03	<0.03	<0.3	<0.3	<0.3	<0.3
Trichloroethene	1.1	<0.2	2.0	3.0	7.7	1.2	<1.0	4.2	<1.0
Vinyl chloride	<0.2	<0.2	<0.2	<0.2	<0.2	<1.8	<1.0	<1.0	<1.0
Tetrachloroethene	--	--	--	<0.03	<0.03	<0.3	<0.3	<0.3	<0.3

Key at end of table.

Table 4-3 (Cont.)

B-17M

Compound	11/88	12/88	1/89	4/89	7/89	10/89	1/90	4/90
Carbon tetrachloride	<200	<500	<24	<3.0	<200	<200	<100	<250
Chloroform	<200	<500	R	<1.2	<100	<100	<50	<130
1,1-dichloroethane	280	<500	<14	260	280	880	360	210
1,1-dichloroethene	580	<1000	<26	120	98	750	<100	<250
Methylene chloride	45	2300	<20	<2.5	<200	<200	<500	<1300
Trans-1,2-dichloroethene	--	--	<20	<78	<200	440	140	<250
Cis-1,2-dichloroethene	--	--	21000	16000	16000	83000	13000	14000
Total-1,2-dichloroethene	170000	65000	21000	16000	16000	84000	13000	14000
1,1,1-trichloroethane	350	<500	1000	240	500	740	330	<75
Trichloroethene	160000	150000	21000	35000	17000	140000	13000	15000
Vinyl chloride	26000	<1500	1100	1000	2200	7600	1200	<250
Tetrachloroethene	--	--	<6.0	<0.8	<60	<60	<30	<75

Key at end of table.

Table 4-3 (Cont.)

B-18M

Compound	11/88	12/88	1/89	4/89	7/89	10/89	1/90	4/90
Carbon tetrachloride	<0.2	<0.5	<0.1	<0.1	<1.2	<1.0	<1.0	<1.0
Chloroform	0.6	<0.5	R	<0.05	<0.5	<0.5	<0.5	<0.5
1,1-dichloroethane	<0.2	<0.5	<0.07	<0.07	<0.7	<0.7	<0.7	<0.7
1,1-dichloroethene	<0.2	<1.0	<0.1	<0.03	<1.3	<1.0	<1.0	<1.0
Methylene chloride	<1.0	2.3	<0.1	<0.1	<2.5	2.8	<5.0	<5.0
Trans-1,2-dichloroethene	--	--	<0.1	<0.1	<1.0	<1.0	<1.0	<1.0
Cis-1,2-dichloroethene	--	--	1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Total-1,2-dichloroethene	<0.2	1.4	1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1,1-trichloroethane	<0.2	<0.5	<0.03	<0.03	<0.3	<0.3	<0.3	<0.3
Trichloroethene	1.0	5.2	61	<0.1	<1.2	<1.0	<1.0	<1.0
Vinyl chloride	<0.2	<2.0	<0.2	<0.2	<1.8	<1.0	<1.0	<1.0
Tetrachloroethene	--	--	<0.03	<0.03	<0.3	<0.3	<0.3	<0.3

Key at end of table.

Table 4-3 (Cont.)

B-19M

Compound	11/88	12/88	1/89	4/89	7/89	10/89	1/90	4/90
Carbon tetrachloride	<1.0	<0.5	<0.1	<0.1	<1.2	<1.0	<5.0	<5.0
Chloroform	<1.0	<0.5	R	<0.05	<0.5	<0.5	19	<2.5
1,1-dichloroethane	<1.0	15	11	66	41	41	150	82
1,1-dichloroethene	<1.0	<1.0	<0.1	4.8	2.7	2.2	16	5.9
Methylene chloride	<1.0	2.1	0.2	<0.1	<2.5	<1.0	<25	<25
Trans-1,2-dichloroethene	--	--	0.5	0.5	2.1	2.6	6.2	<5.0
Cis-1,2-dichloroethene	--	--	27°	100	140	100	220	300
Total-1,2-dichloroethene	<1.0	30	27	100	140	100	230	300
1,1,1-trichloroethane	<1.0	14	23	70	55	47	200	140
Trichloroethene	3.0	7.6	17	120	320	260	310	820
Vinyl chloride	<1.0	<2.0	4.2	6.9	11	3.4	31	19
Tetrachloroethene	--	--	<0.03	<0.03	<0.3	<0.3	<1.5	4.6

Key at end of table.

Table 4-3 (Cont.)

B-20M

Compound	11/88	12/88	1/89	4/89	7/89	10/89	1/90	4/90
Carbon tetrachloride	<1.0	<0.4	<0.1	<0.1	<1.2	<1.0	<1.0	<1.0
Chloroform	<1.0	<0.4	R	<0.05	<0.5	<0.5	0.6	<0.5
1,1-dichloroethane	<1.0	<0.4	<0.07	<0.07	<0.7	<0.7	<0.7	<0.7
1,1-dichloroethene	<1.0	<0.8	<0.1	<0.03	<1.3	<1.0	<1.0	<1.0
Methylene chloride	<1.0	3.8	0.2	<0.1	26	<1.0	<5.0	<5.0
Trans-1,2-dichloroethene	--	--	<0.1	<0.1	<1.0	<1.0	<1.0	<1.0
Cis-1,2-dichloroethene	--	--	<0.1	<0.1	<1.0	<1.0	<1.0	<1.0
Total-1,2-dichloroethene	<1.0	<0.4	<0.1	<0.1	<1.0	<1.0	<1.0	<1.0
1,1,1-trichloroethane	<1.0	<0.4	<0.03	<0.03	<0.3	<0.3	<0.3	<0.3
Trichloroethene	3.0	<0.4	0.5	<0.1	<1.2	<1.0	<1.0	<1.0
Vinyl chloride	<1.0	<2.0	<0.2	<0.2	<1.8	<1.0	<1.0	<1.0
Tetrachloroethene	--	--	<0.03	<0.03	<0.3	<0.3	<0.3	<0.3

Key at end of table.

Table 4-3 (Cont.)

B-21M

Compound	11/88	12/88	1/89	4/89	7/89	10/89	1/90	4/90
Carbon tetrachloride	<1.0	<0.2	<0.1	<0.1	<1.2	<1.0	<1.0	<1.0
Chloroform	<1.0	<0.2	R	<0.05	<0.5	<0.5	1.0	<0.5
1,1-dichloroethane	<1.0	<0.2	<0.07	<0.07	<0.7	<0.7	<0.7	<0.7
1,1-dichloroethene	<1.0	<0.4	<0.1	<0.03	<1.3	<1.0	<1.0	<1.0
Methylene chloride	2.0	1.2	0.1	<0.1	<2.5	<1.0	<5.0	<5.0
Trans-1,2-dichloroethene	--	--	<0.1	<0.1	<0.1	<0.1	<1.0	<1.0
Cis-1,2-dichloroethene	--	--	<1.0	2.0	<1.0	<1.0	24	<1.0
Total-1,2-dichloroethene	3.2	<0.2	<1.0	2.0	<1.0	<1.0	24	<1.0
1,1,1-trichloroethane	<1.0	<0.2	<0.03	<0.03	<0.3	<0.3	<0.3	<0.3
Trichloroethene	8.2	<0.2	2.0	6.8	<1.2	<1.0	4.5	<1.0
Vinyl chloride	<1.0	<0.6	<0.2	<0.2	<1.8	<1.0	<1.0	<1.0
Tetrachloroethene	--	--	<0.03	<0.03	<0.3	<0.3	<0.3	<0.3

Key at end of table.

Table 4-3 (Cont.)

B-22M

Compound	11/88	12/88	2/89	4/89	7/89	10/89	1/90	4/90
Carbon tetrachloride	<1.0	<1.0	<0.1	<0.1	<10	<1.0	<1.0	<10
Chloroform	<1.0	<1.0	R	67	<5.0	<0.5	<0.5	<5.0
1,1-dichloroethane	<1.0	<1.0	<0.07	3.3	19	<0.7	25	14
1,1-dichloroethene	<1.0	<2.0	<0.1	2.9	12	<1.0	19	<10
Methylene chloride	3.0	3.5	<0.1	<0.1	<10	<1.0	<5.0	<50
Trans-1,2-dichloroethene	--	--	0.5	5.3	15	<1.0	24	<10
Cis-1,2-dichloroethene	--	--	24	280	2800	17	4400	1600
Total-1,2-dichloroethene	220	130	25	290	2800	17	4400	1600
1,1,1-trichloroethane	<1.0	<1.0	<0.03	<0.03	17	<0.3	<0.3	<3.0
Trichloroethene	23	12	4.5	19	360	<1.0	750	160
Vinyl chloride	<1.0	<3.0	2.3	3.8	260	<1.0	93	58
Tetrachloroethene	--	--	<0.03	<0.03	<3.0	<0.3	<0.3	<3.0

Key at end of table.

Table 4-3 (Cont.)

B-23M

Compound	1/89	4/89	7/89	10/89	1/90	4/90
Carbon tetrachloride	<0.1	<0.1	<1.2	<10	<10	<10
Chloroform	R	<0.05	<0.5	<5.0	<5.0	<5.0
1,1-dichloroethane	2.4	4.0	3.5	<7.0	7.7	<7.0
1,1-dichloroethene	2.6	3.7	3.9	4.7	<10	<10
Methylene chloride	<0.1	<0.1	<2.5	<10	71	<50
Trans-1,2-dichloroethene	4.7	<0.1	3.8	14	20	<10
Cis-1,2-dichloroethene	900	720	1100	750	2300	1100
Total-1,2-dichloroethene	900	720	1100	760	2300	1100
1,1,1-trichloroethane	<0.03	<0.03	<0.3	<3.0	<3.0	<3.0
Trichloroethene	2.6	2.1	1.5	13	71	63
Vinyl chloride	46	66	100	65	86	37
Tetrachloroethene	<0.03	<0.03	<0.3	<3.0	<3.0	<3.0

Key at end of table.

Table 4-3 (Cont.)

B-24M

Compound	1/89	4/89	7/89	10/89	1/90	4/90
Carbon tetrachloride	<0.1	<0.1	<1.2	1.8	<1.0	<1.0
Chloroform	R	<0.05	<0.5	<0.5	<0.5	<0.5
1,1-dichloroethane	<0.07	<0.07	<0.7	<0.7	<0.7	<0.7
1,1-dichloroethene	<0.1	<0.03	<1.3	<1.0	<1.0	<1.0
Methylene chloride	0.1	<0.1	<2.5	<1.0	<5.0	<5.0
Trans-1,2-dichloroethene	<0.1	<0.1	<1.0	<1.0	<1.0	<1.0
Cis-1,2-dichloroethene	1.0	2.0	2.2	44	3.3	1.6
Total-1,2-dichloroethene	1.0	2.0	2.2	44	3.3	1.6
1,1,1-trichloroethane	<0.03	<0.03	<0.3	2.1	<0.3	<0.3
Trichloroethene	6.0	11	16	220	17	11
Vinyl chloride	<0.2	<0.2	<1.8	1.6	<1.0	<1.0
Tetrachloroethene	<0.03	<0.03	<0.3	<0.3	<0.3	<0.3

Key at end of table.

Table 4-3 (Cont.)

B-25M

Compound	1/89	4/89	7/89	10/89	1/90	4/90
Carbon tetrachloride	<0.1	<0.1	<1.2	<1.0	<1.0	<1.0
Chloroform	R	<0.05	<0.5	<0.5	<0.5	<0.5
1,1-dichloroethane	<0.07	<0.07	<0.7	<0.7	<0.7	<0.7
1,1-dichloroethene	<0.1	<0.03	<1.3	<1.0	<1.0	<1.0
Methylene chloride	0.2	<0.1	<2.5	<1.0	6.4	<5.0
Trans-1,2-dichloroethene	<0.1	<0.1	<1.0	<1.0	<1.0	<1.0
Cis-1,2-dichloroethene	<0.1	<0.1	<1.0	<1.0	23	<1.0
Total-1,2-dichloroethene	<0.1	<0.1	<1.0	<1.0	23	<1.0
1,1,1-trichloroethane	<0.03	<0.03	<0.3	<0.3	<0.3	<0.3
Trichloroethene	0.8	0.1	<1.2	<1.0	9.8	<1.0
Vinyl chloride	<0.2	<0.2	<1.8	<1.0	1.4	<1.0
Tetrachloroethene	<0.03	<0.03	<0.3	<0.3	<0.3	<0.3

Key at end of table.

Table 4-3 (Cont.)

B-26M

Compound	1/89	4/89	7/89	10/89	1/90	4/90
Carbon tetrachloride	<0.1	<0.1	<1.2	<1.0	<1.0	<1.0
Chloroform	R	<0.05	<0.5	<0.5	<0.5	<0.5
1,1-dichloroethane	<0.07	<0.07	<0.7	<0.7	<0.7	<0.7
1,1-dichloroethene	<0.1	<0.03	<1.3	<1.0	<1.0	<1.0
Methylene chloride	0.2	<0.1	<2.5	<1.0	<5.0	<5.0
Trans-1,2-dichloroethene	<0.1	<0.1	<1.0	<1.0	<1.0	<1.0
Cis-1,2-dichloroethene	<0.1	<0.1	<1.0	<1.0	<1.0	<1.0
Total-1,2-dichloroethene	<0.1	<0.1	<1.0	<1.0	<1.0	<1.0
1,1,1-trichloroethane	<0.03	<0.03	<0.3	<0.3	<0.3	<0.3
Trichloroethene	1.3	<0.1	<1.2	3.1	<1.0	<1.0
Vinyl chloride	<0.2	<0.2	<1.8	<1.0	<1.0	<1.0
Tetrachloroethene	<0.03	<0.03	<0.3	<0.3	<0.3	<0.3

Key at end of table.

Table 4-3 (Cont.)

B-27M

Compound	4/89	7/89	10/89	1/90	4/90
Carbon tetrachloride	<0.1	<1.2	<200	<10	<10
Chloroform	<0.05	<0.5	<100	<5.0	<5.0
1,1-dichloroethane	0.4	<0.7	<140	<7.0	<7.0
1,1-dichloroethene	0.6	<1.3	73	<10	<10
Methylene chloride	<0.1	<2.5	<200	<50	<50
Trans-1,2-dichloroethene	0.6	<1.0	<200	<10	<10
Cis-1,2-dichloroethene	25	<1.0	8000	990	530
Total-1,2-dichloroethene	26	<1.0	8000	990	530
1,1,1-trichloroethane	<0.03	<0.3	<60	<3.0	<3.0
Trichloroethene	11	<1.2	<200	<10	<10
Vinyl chloride	4.4	<1.8	2000	91	74
Tetrachloroethene	<0.03	<0.3	<60	<3.0	<3.0

Key at end of table.

Table 4-3 (Cont.)

Compound	B-28M 1/90	B-28M 4/90	B-29M 1/90	B-29M 4/90	B-30M 1/90	B-30M 4/90	B-31M 1/90	B-31M 4/90
Carbon tetrachloride	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Chloroform	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
1,1-dichloroethane	<0.7	<0.7	1.3	<0.7	<0.7	<0.7	<0.7	<0.7
1,1-dichloroethene	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Methylene chloride	<5.0	<5.0	<5.0	<5.0	6.3	<5.0	<5.0	<5.0
Trans-1,2-dichloroethene	<1.0	<1.0	3.6	<1.0	3.3	<1.0	<1.0	<1.0
Cis-1,2-dichloroethene	<1.0	<1.0	290	73	110	42	2.7	2.0
Total-1,2-dichloroethene	<1.0	<1.0	300	73	110	42	2.7	2.0
1,1,1-trichloroethane	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
Trichloroethene	<1.0	<1.0	12	2.8	2.0	<1.0	9.1	6.9
Vinyl chloride	<1.0	<1.0	16	2.6	12	<1.0	<1.0	<1.0
Tetrachloroethene	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3

D = Not detected.

R = Value unusable, due to chloroform contamination in the dilution water and decontamination blank.

-- = Not analyzed for this compound.

Table 4-4

ANALYTICAL SUMMARY: UNDERGROUND TANK SAMPLING - CHLORINATED ORGANICS
($\mu g/L$)

	Tank No.:	T-1		T-2		T-3		T-4		T-5		T-6E		T-6W	
Compound	Date:	5-87	6-89	5-87	6-89	5-87	6-89	5-87	6-89	5-87	6-89	5-87	6-89	5-87	6-89
Carbon Tetrachloride		<2	<.3	<0.4	<.3	<0.4	<.3	<0.4	<.3	<0.4	<.3	<0.4	<.3	<0.4	--
Chloroform		<1	<.4	<0.2	<.4	<0.2	<.4	<0.2	<.4	<0.2	<.4	<0.2	<.4	<0.2	--
1,1-Dichloroethane		<1	<.5	<0.2	<.5	<0.2	<.5	<0.2	<.5	<0.2	<0.65	<0.2	<.5	<0.2	--
1,1-Dichloroethene		<2	<.8	<0.4	<.8	<0.4	<.8	<0.4	<.8	<0.4	<.8	<0.4	<.8	<0.4	--
Total 1,2-Dichloroethene		3.1	<.3	1.5	<.3	1.2	<.3	0.74	<.3	0.38	<.3	<0.4	<.3	<0.4	--
Methylene Chloride		<1	<.8	<0.2	1.5	<0.2	<.8	0.38	6.0	0.37	3.1	<0.2	<.8	<0.2	--
1,1,1-Trichloroethane		<2	<.4	<0.4	<.4	<0.4	<.4	<0.4	<.4	<0.4	.4	<0.4	<.4	<0.4	--
Trichloroethene		120	<1.0	70	<1.0	76	<1.0	20	<1.0	26	<1.0	17	<1.0	14	--
Vinyl Chloride		<3	<.8	<0.6	<.8	<0.6	<.8	<0.6	<.8	<0.6	<.8	<0.6	<.8	<0.6	--

	Tank No.:	T-7		T-8*		T-9**		T-10E		T-10W	
Compound	Date:	5-87	6-89	5-87	6-89	5-87	6-89	5-87	6-89	5-87	6-89
Carbon Tetrachloride		<0.4	--	<20	<60	<2,000	<6,000	<20	<3.0	<200	<300
Chloroform		<0.2	<.4	<30	<80	<1,000	11,000J	<20	7.5	<100	660
1,1-Dichloroethane		<0.2	<.5	<20	<100	<1,000	<10,000	82	<5.0	47	<500
1,1-Dichloroethene		<0.4	<.8	<20	<160	64	<16,000	6.8	4.0J	<200	<800
Total 1,2-Dichloroethene		0.80	<.3	2,400	7,926	57,000	35,000	650	79.8	7,000	11,150
Methylene Chloride		0.30	2.4	<60	130J	<2,000	16,000	<20	4.9J	<200	2,000
1,1,1-Trichloroethane		<0.4	<.4	<20	<80	<2,000	<8,000	74	<5.0	210	<400
Trichloroethene		20	2.1	470	4,100	790,000	960,000	690	88	47,000	<11,000
Vinyl Chloride		<0.6	<.8	740	40J	1,900	<16,000	73	55	640	<330J

J = Estimated value (below detection limit).

*Abandoned pump house.
**Abandoned chlorine contact tank.

5-87 Samples analyzed by RECRA Environmental for chlorinated organics using EPA Method 601.
6-89 Samples analyzed by AES for purgeable halocarbons using Method 5030/8010.

Notes: 1. Tanks T-8, T-9, T-10E, and T-10W sampled in 6-89 from bottom of tank liquid.
2. On 6-89, tanks T-1 through T-7 were analyzed for Trans-1,2-Dichloroethene rather than Total Dichloroethene. The data reported above for these tanks under Total Dichloroethene is for Trans-1,2-Dichloroethene only.

- o Fine-grained silts and clays deposited in lakes created behind the receding ice sheets;
- o As moraine deposits of glacial till; and
- o As small discontinuous sand and gravel deposits from local streams.

The majority of the borings drilled at the Carborundum facility encountered the silty-clay lacustrine deposits with random zones of sand and gravel found in some areas at the bottom of the overburden.

The underlying bedrock is composed of the Lockport Dolomite. It was investigated in this study to a maximum depth of 70 feet from the surface. Eighty-five percent of the wells drilled on the facility for this investigation were only drilled into the upper 5 to 15 feet of bedrock. Regional studies of the Lockport Dolomite have shown the upper 10 to 20 feet to be significantly more highly fractured and consequently more transmissive than the lower bedrock zones (Zenger 1965; Johnston 1964). The degree of fracturing in this upper bedrock zone was not found to be uniform across the site. For example, shallow bedrock fracturing in B-8M was logged by the site geologist as being "broken with fractures too numerous to count," in the upper 2 feet, whereas the shallow bedrock was noted in B-3M to be "hard, thin- to medium-bedded dolostone (with) fractures tight to open" and "hard to very hard, weathered to sound," in B-17M (see Appendix A).

In general, fewer fractures are encountered in the deeper intervals in the three deep monitoring wells drilled greater than 15 feet into bedrock. However, no consistent trend of decreasing fracture frequency was observed. Loss of circulation water into large fractures occurred at 26.3 feet in deep well B-19M when a horizontal bedding plane was encountered; however, good return on drilling water occurred through the drilling of the bedrock interval in deep wells B-18M and B-20M.

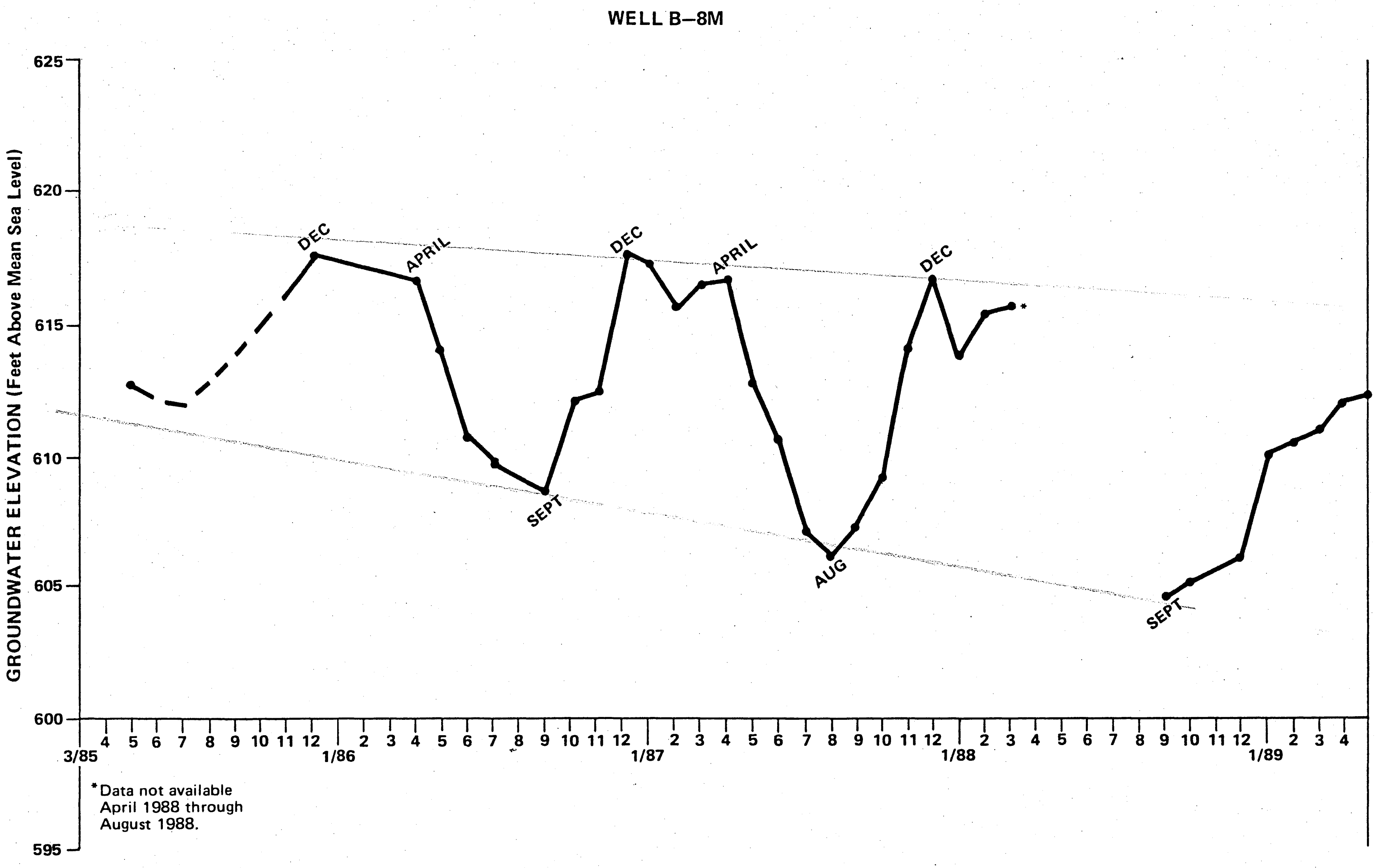
The bedrock fracture system within the Lockport Dolomite is more complex than a simple highly fractured zone at the top underlain by less fractured zones. As discussed in Section 2, the primary fracture orientation critical to groundwater flow are the bedding plane fractures. At depths greater than those investigated in this study, bedding plane fractures have been correlated across large areas as somewhat unique and isolated aquifer units. The majority (at least 80%) of fractures logged from cores obtained during monitoring well installation were horizontal bedding plane fractures. This sampling technique, however, is heavily weighted toward finding more horizontal fractures than vertical fractures because horizontal fractures are perpendicular to vertical cores whereas vertical fractures are parallel to vertical cores. A conjugate northwest-southeast (NW-SE) and northeast-southwest (NE-SW) fracture system may also trend through the Niagara Falls area and may be present in the study area (Miller and Kappel 1987).

A vertical fracture trend was evidenced in the seismic refraction data as small "lows" in the depth to bedrock and by "noisy" and anomalous first break arrivals. These could be correlated across seismic lines into a NW-SE and NE-SW fracture system (E & E 1987). This conjugate fracture trend has also been observed in regional studies of the Lockport Dolomite in the Niagara Falls area (Miller and Kappel 1989). Further local evidence of a vertical fracture system can be interpreted from the pumping test data; for example, B-19M, a deep bedrock well, responded to pumping the shallow bedrock zone 20 feet above the screened interval in B-19M. During the pumping tests, the monitoring wells also did not respond to pumping with drawdowns directly proportional to their distance from the pumping well. Wells farther away which apparently intersect fractures connected with the pumping well drew down more significantly than closer wells which may have been drilled into relatively nonfractured fault blocks. The complex interconnected network of bedding plane and conjugate vertical fractures can only be partially characterized on a local scale by remote sensing techniques.

4.2.2 Hydrogeology

Groundwater occurs in both the unconsolidated deposits and in the bedrock beneath the Carborundum facility. The groundwater elevations drop quite significantly during the summer and early fall and increase in the late winter and spring. A sample hydrograph from one of the monitoring wells on the facility is presented in Figure 4-4.

Seasonal water level in the shallow bedrock wells has been observed to vary 10 feet on the average but in some places as much as 15 feet



*Data not available April 1988 through August 1988.

Figure 4–4 HYDROGRAPH OF B–8M SHOWING SEASONAL FLUCTUATIONS IN GROUNDWATER ELEVATION (see Table 4-5). The magnitude of this fluctuation is not uniform across the facility. Wells in the southwest corner of the site only fluctuate seasonally on the order of 4 to 5 feet. These lower fluctuations are approximately the same as regional seasonal trends reportedly observed elsewhere in the shallow bedrock interval in the Niagara Falls area (Johnston 1964).

During the winter and spring months, the shallow bedrock aquifer is confined across the majority of the study area, having a hydraulic head above the top of bedrock (see Figures 4-5, 4-6, and Plate 2). On the average, high water levels reach 3 to 5 feet below the ground surface during the late winter and early spring. P-2, the active plant production well, frequently flows on the surface in the early spring. The tight overburden material acts as a low-permeability confining layer to the bedrock aquifer. In the southwest portion of the site, downgradient of the hydraulic boundary, the water level in shallow bedrock wells generally is at or below the top of the bedrock throughout the year. At the highest point, the water depth in these wells is still between 12 and 20 feet from the surface.

During the summer and fall, the head in the shallow bedrock drops to its lowest level, generally reaching a minimum in September (Figures 4-4, 4-7, and 4-8). The shallow bedrock wells on the western two thirds of the study area become unconfined in the late summer because the water level falls below the top of bedrock. Only B-8M, B-7M, B-5M, and B-6M, on the eastern side of the study area, almost always remain confined (over the 5 years monitored). Snow and rainfall are fairly uniform throughout the year in the Niagara Falls area. Consequently, the cause of the seasonal fluctuations in groundwater elevations is more a product of temperature than of precipitation. The temperature controls the rate of evapotranspiration which is highest in the summer and fall. Infiltration during this period is reduced significantly due to the high evapotranspiration rates. Thus, groundwater levels become increasingly depressed in the late summer and early fall.

Groundwater in the overburden was not studied extensively because the silt and clay deposits of which it is primarily composed are too tight to qualify this interval as an "aquifer" capable of transmitting adequate quantities of water for domestic use. Discontinuous sand and

Table 4-5

GROUNDWATER ELEVATIONS IN SHALLOW BEDROCK

Well Number	8/22/84	10/06/84	3/08/85	5/20/85	12/03/85	4/28/86	5/23/86	6/26/86	7/29/86	8/26/86	9/30/86	10/30/86	11/17/86	12/10/86
Shallow wells:														
B-3	605.14	603.74	614.07	609.98	612.66	613.06	610.85	608.27	607.49	606.97	605.56	608.12	609.68	613.33
B-4	597.99	598.69	601.84	600.51	609.39	602.07	600.70	599.77	599.51	599.36	599.22	599.99	600.55	601.83
B-5	605.92	603.62	619.50	612.53	618.69	617.68	614.57	609.81	608.93	608.47	607.84	612.67	N/A	617.95
B-6	599.52	603.12	611.80	606.84	612.18	611.33	610.33	606.68	605.80	605.17	606.24	608.00	608.00	612.33
B-7	603.77	602.77	613.94	608.68	613.27	612.27	610.90	607.10	606.13	605.74	606.19	608.82	608.97	N/A
B-8	606.78	606.08	618.42	612.89	617.58	616.78	614.16	610.60	609.88	613.97	608.74	612.26	612.68	617.53
B-9	—	—	—	—	—	—	—	—	—	—	—	—	—	618.00
B-10	—	—	—	—	—	—	—	—	—	—	—	—	—	619.40
B-11	—	—	—	—	—	—	—	—	—	—	—	—	—	617.27
B-12	—	—	—	—	—	—	—	—	—	—	—	—	—	615.13
B-13	—	—	—	—	—	—	—	—	—	—	—	—	—	603.63
B-14	—	—	—	—	—	—	—	—	—	—	—	—	—	**
B-15	—	—	—	—	—	—	—	—	—	—	—	—	—	—
B-16	—	—	—	—	—	—	—	—	—	—	—	—	—	—
B-17	—	—	—	—	—	—	—	—	—	—	—	—	—	—
B-21	—	—	—	—	—	—	—	—	—	—	—	—	—	—
B-22	—	—	—	—	—	—	—	—	—	—	—	—	—	—
B-23	—	—	—	—	—	—	—	—	—	—	—	—	—	—
B-24	—	—	—	—	—	—	—	—	—	—	—	—	—	—
B-25	—	—	—	—	—	—	—	—	—	—	—	—	—	—
B-26	—	—	—	—	—	—	—	—	—	—	—	—	—	—
B-27	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Deep Wells:														
B-18	—	—	—	—	—	—	—	—	—	—	—	—	—	—
B-19	—	—	—	—	—	—	—	—	—	—	—	—	—	—
B-20	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Pumping Wells:														
P-2	N/A	N/A	Artesian	N/A	N/A	N/A	614.16	614.04	N/A	N/A	N/A	N/A	N/A	Artesian
P-3	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Key and notes at end of table.

Table 4-5 (Cont.)

Well Number	12/31/86	1/19/87	2/02/87	3/16/87	4/20/87	5/26/87	6/23/87	7/20/87	8/20/87	9/24/87	10/27/87	11/30/87	12/31/87
Shallow wells:													
B-3	613.22	613.53	612.20	612.98	612.85	610.13	608.03	605.71	603.60	604.61	607.05	609.44	613.81
B-4	601.70	601.92	601.82	602.03	601.72	600.62	600.14	599.85	598.77	598.76	599.17	600.44	601.96
B-5	617.71	617.65	615.72	617.11	616.35	611.98	608.25	602.92	602.30	605.82	608.15	614.30	617.21
B-6	611.73	611.97	610.43	611.10	613.10	608.31	605.85	603.62	603.10	604.44	604.95	609.39	610.94
B-7	613.01	613.26	611.54	612.39	612.28	608.94	606.39	603.60	602.40	604.60	605.94	610.29	612.44
B-8	617.26**	617.58	615.68	616.60	616.78	612.79	610.37	607.19	606.17	607.31	609.33	614.20	616.93
B-9	617.94	617.83	616.56	617.55	617.16	613.26	610.38	606.71	604.38	606.72	609.19	613.03	617.87
B-10	618.97	619.48	617.70	618.82	618.59	614.94	611.75	609.21	606.71	608.62	610.53	613.77	618.89
B-11	617.12	617.25	615.65	616.63	616.30	612.48	609.45	604.56	603.46	606.01	608.94	614.53	616.73
B-12	615.20	615.13	614.65	614.98	614.62	611.07	608.56	604.94	603.01	604.86	608.01	610.71	615.15
B-13	603.86	603.67	603.17	603.59	603.56	601.72	600.82	599.90	599.53	599.94	600.05	601.32	603.79
B-14	617.42**	617.70	615.64	616.81	616.61	611.95	608.65	603.89	603.23	605.91	608.42	614.61	617.34
B-15	—	—	—	—	—	—	—	—	—	—	—	—	—
B-16	—	—	—	—	—	—	—	—	—	—	—	—	—
B-17	—	—	—	—	—	—	—	—	—	—	—	—	—
B-21	—	—	—	—	—	—	—	—	—	—	—	—	—
B-22	—	—	—	—	—	—	—	—	—	—	—	—	—
B-23	—	—	—	—	—	—	—	—	—	—	—	—	—
B-24	—	—	—	—	—	—	—	—	—	—	—	—	—
B-25	—	—	—	—	—	—	—	—	—	—	—	—	—
B-26	—	—	—	—	—	—	—	—	—	—	—	—	—
B-27	—	—	—	—	—	—	—	—	—	—	—	—	—
Deep Wells:													
B-18	—	—	—	—	—	—	—	—	—	—	—	—	—
B-19	—	—	—	—	—	—	—	—	—	—	—	—	—
B-20	—	—	—	—	—	—	—	—	—	—	—	—	—
Pumping Wells:													
P-2	617.44	Artesian	N/A	N/A	615.93	605.93	614.16	612.67	613.16	605.93	608.16	614.67	617.61
P-3	—	—	—	—	—	—	—	—	—	—	—	—	—

Key and notes at end of table.

Table 4-5 (Cont.)

Well Number	1/29/88	2/18/88	3/21/88	8/10/88	9/16/88	10/24/88	11/10/88	12/15/88	1/27/89	2/21/89	3/22/89	4/12/89	5/?/89
Shallow wells:													
B-3	611.20	611.72	612.17	605.78	602.49	603.28	607.47	604.17	608.27	606.09	612.72	613.68	614.14
B-4	601.34	601.40	601.26	599.88	598.78	598.68	598.57	598.76	599.53	599.92	600.68	601.46	602.08
B-5	614.28	618.20	615.62	607.08	599.18	599.98	600.63	601.07	609.42	609.00	616.92	617.86	618.06
B-6	609.56	610.82	610.71	603.70	600.38	600.33	600.65	601.70	606.92	606.88	611.45	611.94	612.11
B-7	610.16	611.63	611.41	604.52	600.44	600.29	600.55	602.95	607.65	607.17	612.30	613.18	613.19
B-8	613.90	615.45	615.59	607.85	604.88	605.28	605.38	606.26	610.13	610.69	616.09	617.32	617.47
B-9	614.91	616.28	616.50	608.44	602.02	N/A	595.00	605.29	610.37	610.70	616.23	618.12	618.32
B-10	605.70	617.40	617.96	607.48	605.17	603.91	602.88	608.48	611.31	611.58	616.47	619.23	619.56
B-11	613.77	615.61	615.70	607.67	601.83	604.45	601.39	604.43	610.12	609.72	616.17	617.10	617.13
B-12	612.90	612.61	613.89	606.89	602.06	604.34	601.80	604.13	608.77	608.68	613.58	614.00	615.62
B-13	603.32	*	603.53	599.90	592.64	600.35	600.21	603.19	*	600.04	602.98	603.28	603.65
B-14	614.02	615.71	616.39	607.00	603.45	N/A	602.84	604.21	609.66	608.91	616.48	617.50	617.49
B-15	615.64	617.66	617.91	609.99	608.02	607.60	608.71	610.10	612.20	612.22	617.68	619.37	620.10
B-16	614.20	616.14	616.01	607.09	605.86	599.90	600.14	602.61	609.97	609.12	616.70	617.97	617.78
B-17	—	—	—	—	—	602.29	602.15	604.33	608.41	608.66	613.02	614.11	614.50
B-21	—	—	—	—	—	—	600.71	604.75	609.81	609.42	616.27	617.45	617.55
B-22	—	—	—	—	—	—	592.33	593.77	594.46	595.07	597.77	598.71	599.13
B-23	—	—	—	—	—	—	—	—	593.42	593.69	593.78	595.03	595.48
B-24	—	—	—	—	—	—	—	—	601.34	601.42	603.90	605.38	606.05
B-25	—	—	—	—	—	—	—	—	605.53	606.55	609.18	610.31	610.74
B-26	—	—	—	—	—	—	—	—	606.67	606.60	610.52	611.19	611.49
B-27	—	—	—	—	—	—	—	—	—	609.09	615.62	617.46	617.71
Deep Wells:													
B-18	—	—	—	—	—	—	599.62	603.31	608.32	607.57	614.19	615.31	615.67
B-19	—	—	—	—	—	—	598.22	601.26	605.23	604.74	610.82	611.80	612.68
B-20	—	—	—	—	—	—	600.61	602.51	606.23	605.95	609.93	610.51	610.82
Pumping Wells:													
P-2	614.79	616.26	616.27	607.26	613.98	608.74	611.26	610.03	N/A	609.63	615.66	618.16	618.16
P-3	—	—	—	—	—	—	600.07	604.37	609.75	609.10	616.77	617.95	618.12

Key and notes at end of table.

Table 4-5 (Cont.)

Well Number	7/12/89	10/18/89	1/24/90	4/24/90
Shallow wells:				
B-3	612.44	605.14	613.84	614.29
B-4	600.24	599.29	601.24	602.54
B-5	614.72	604.98	617.98	617.88
B-6	609.87	602.87	612.27	611.87
B-7	610.82	603.07	613.32	613.17
B-8	615.02	606.42	617.17	617.47
B-9	615.73	606.48	617.58	618.38
B-10	616.44	607.74	617.89	619.94
B-11	615.16	605.36	616.91	616.63
B-12	613.52	605.17	615.17	615.94
B-13	602.54	599.50	605.10	604.30
B-14	614.90	605.15	617.85	617.50
B-15	616.23	608.73	618.23	619.68
B-16	614.98	604.93	618.18	618.13
B-17	612.68	605.27	614.77	614.97
B-21	614.71	605.21	617.26	617.56
B-22	597.64	596.04	597.64	599.39
B-23	594.56	591.81	594.41	595.66
B-24	604.15	598.45	604.85	606.63
B-25	609.07	602.21	609.79	610.96
B-26	609.17	602.76	610.81	611.57
B-27	614.94	605.04	618.02	617.84
B-28	—	—	591.77	594.12
B-29	—	—	589.51	591.16
B-30	—	—	589.73	591.48
B-31	—	—	608.33	607.58
Deep Wells:				
B-18	612.58	603.89	615.24	615.64
B-19	610.11	601.81	611.46	613.06
B-20	608.65	602.10	610.75	610.35
Pumping Wells:				
P-2	614.41	604.95	Artesian	Artesian
P-3	614.96	604.90	617.70	618.10

NOTES:

1. All water depths were measured from top of external casing prior to April 1989. Thereafter, water levels were measured from top of internal casing.
2. All water level measurements dated 1987 and earlier are referenced to E & E-surveyed top of external casing (except P-2, for which there was no E & E survey elevation). Therefore, the Tripi surveyed elevation was used for all measurements on P-2).
3. Water levels measured January 1988 through and including March 1989 are referenced to the Tripi-surveyed top of external casing.
4. Water levels measured from April 1989 to present are referenced to the Tripi-surveyed top of internal casing.

Key:

*Obstruction in well due to freeze.
**Water frozen in well.
N/A = No measurement available.

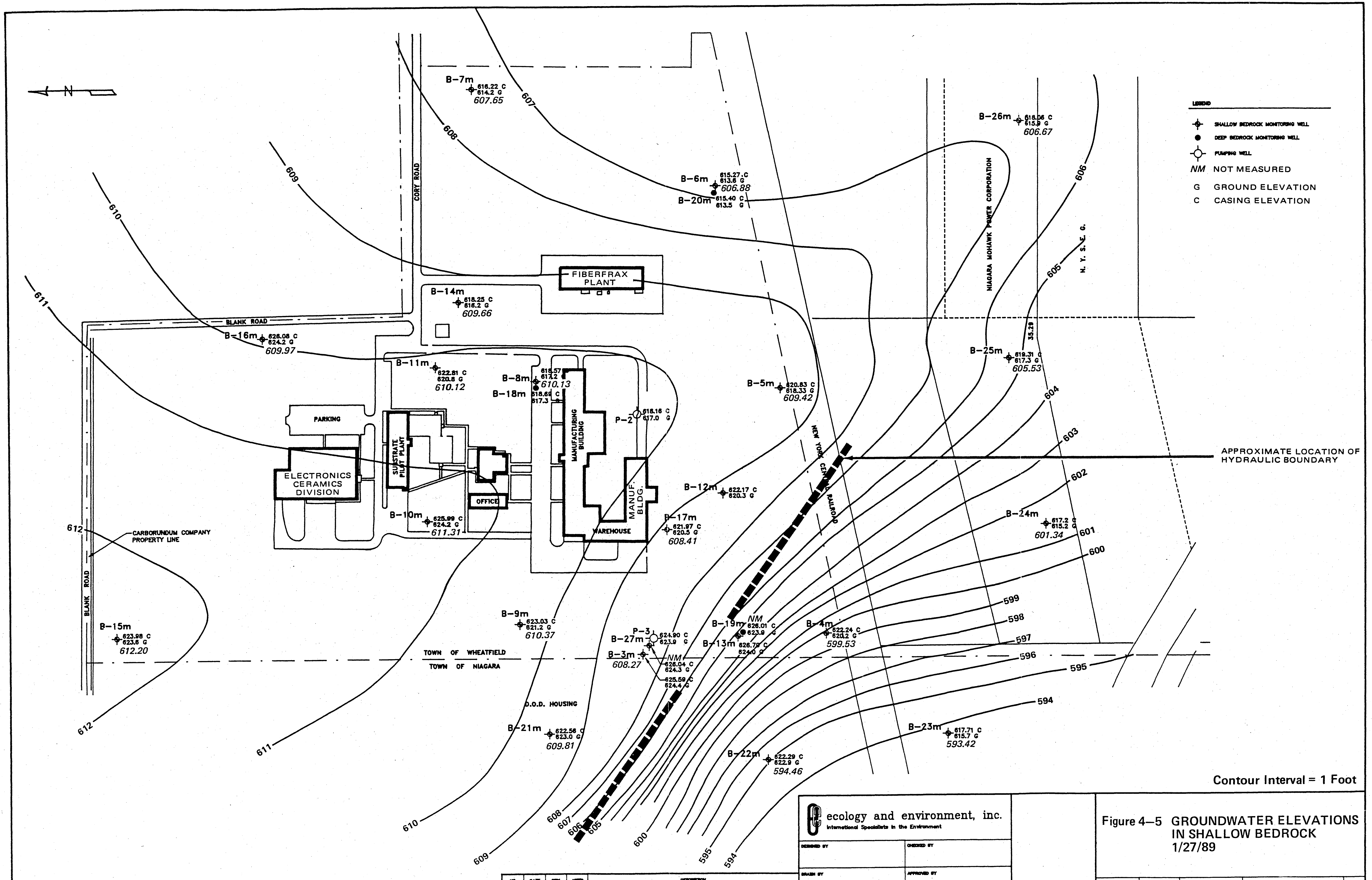


Figure 4–5 GROUNDWATER ELEVATIONS IN SHALLOW BEDROCK 1/27/89

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SCALE	DATE ISSUED	C.A.D. FILE NO.	DRAWING NO.	REV.
1'' = 200'		CZ2MWLOC		

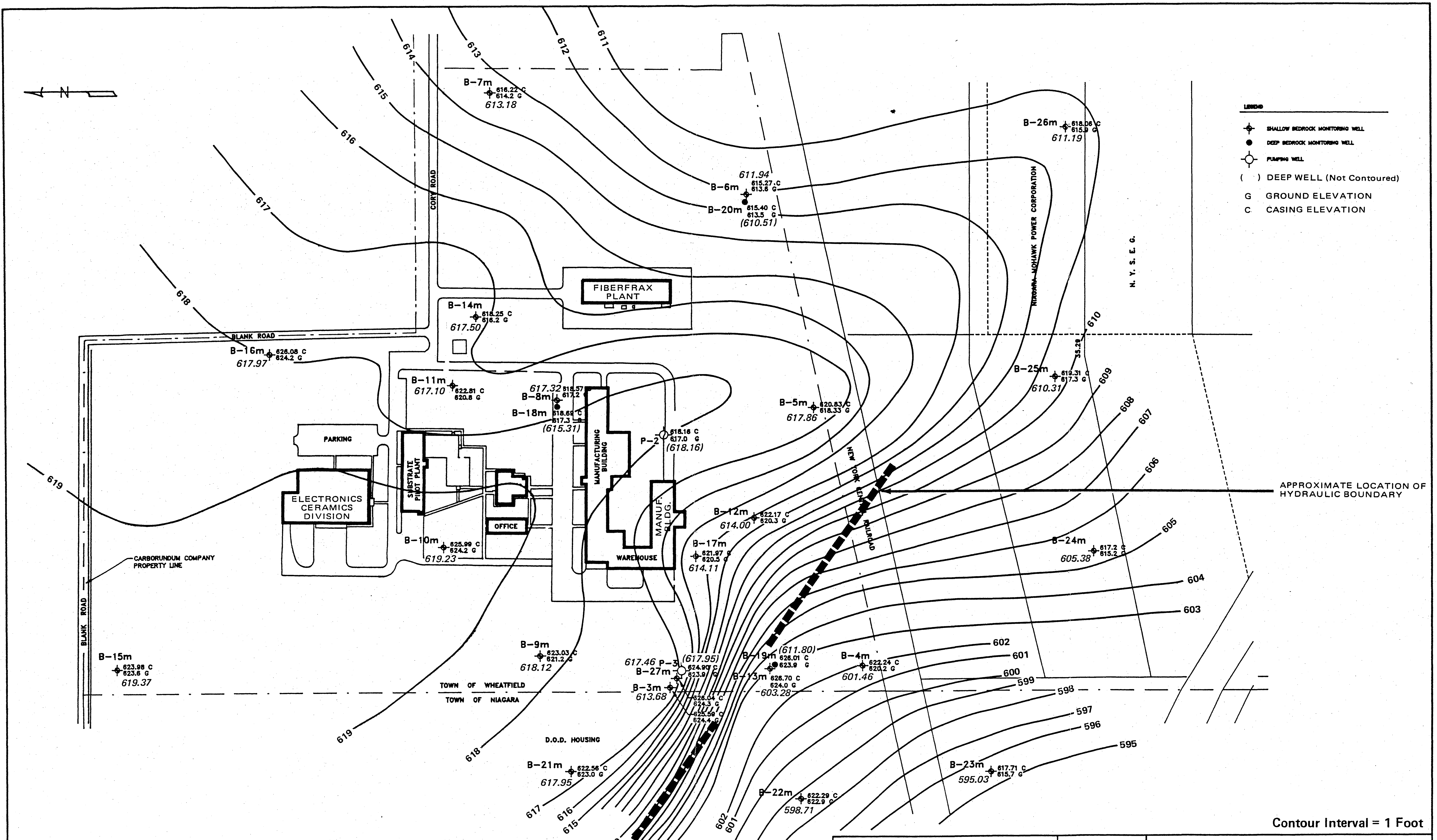

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Figure 4–6 GROUNDWATER ELEVATIONS IN SHALLOW BEDROCK 4/12/89

SCALE	DATE ISSUED	C.A.D. FILE NO.	DRAWING NO.	REV.
1'' = 200'		CZ2MWLOC		

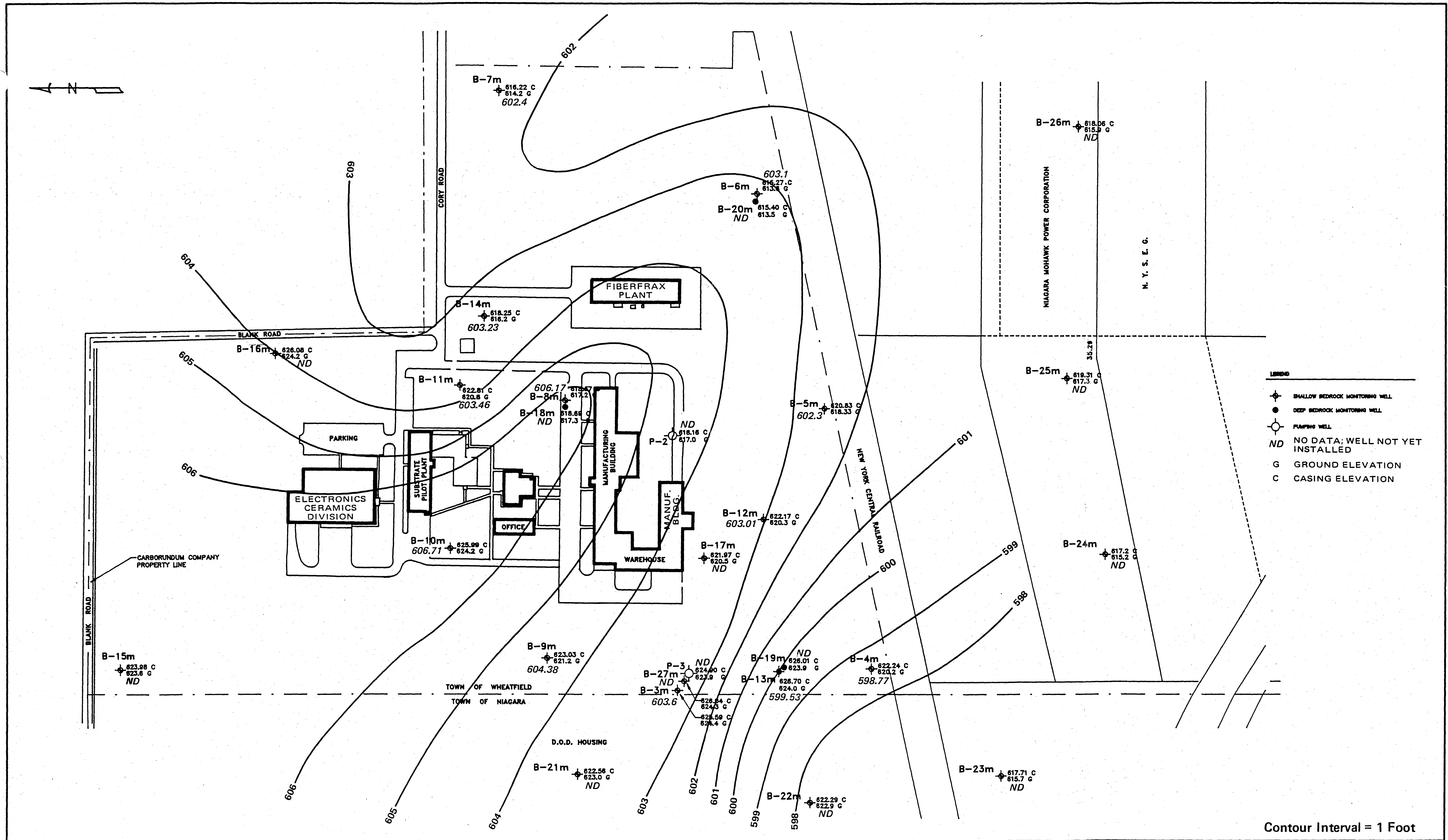

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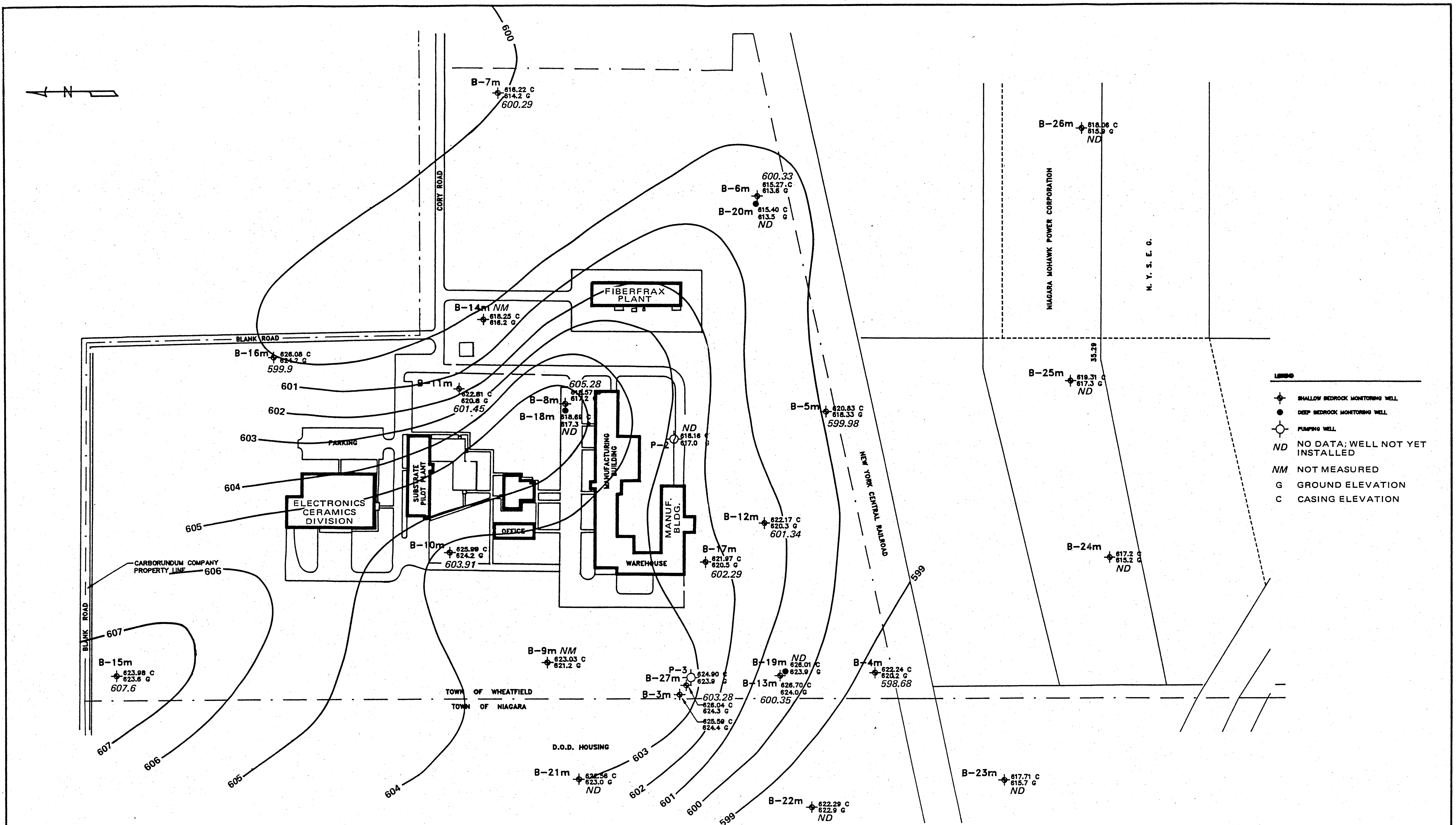
Figure 4–7 WATER ELEVATIONS IN SHALLOW BEDROCK 8/20/87

SCALE	DATE ISSUED	C.A.D. FILE NO.	DRAWING NO.	REV.
1'' = 200'		CZ2MWLOC		



Contour Interval = 1 Foot

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Figure 4–8 WATER ELEVATIONS IN SHALLOW BEDROCK 10/24/88

SCALE	DATE ISSUED	C.A.D. FILE NO.	DRAWING NO.	REV.
1'' = 200'		CZ2MWLOC		

gravel channel deposits are used infrequently for domestic and small farm use. However, from examination of boring logs contained in Appendix A, these units are relatively thin, occur at random stratigraphic positions, and are often suspended in matrices of silts and clays. Most likely these units resulted from the deposition within lakes, periodic braid channels or from sheet-flow processes on glacial outwash plains during glacial recession at the conclusion of the most recent Pleistocene Ice Age. This interpretation is based on regional characteristics of the surficial geology of Niagara County and the above-noted facies characteristics of the overburden deposits in the area of the Carborundum facility. There was not sufficient surface water present to effectively sort gravels and sands from more fine-grained silts and clays or to develop gravel and sand deposits that had a significant areal extent. The result of these random depositional processes was to produce very small and poorly-sorted gravel and sand lenses that are not likely to transmit significant amounts of groundwater or chlorinated organics. Therefore, the overburden is considered to be a saturated aquitard overlying the primary bedrock aquifer.

Seasonal groundwater fluctuations in the overburden were monitored by piezometers for the geotechnical investigation in 1982 before any bedrock groundwater monitoring wells were installed (see Table 4-6). Some of the geotechnical borings flowed on the surface during installation in the spring of 1982. In general, it appears that the groundwater elevation in the overburden comes very close to or above the surface during the wet seasons (i.e., March - April 1983, Table 4-6). Standing water was also observed during the field investigations in 1988 and 1989 in early spring and late fall. However, the vertical gradient from the overburden to the bedrock and the relationship between their seasonal groundwater fluctuations cannot be evaluated without synchronous groundwater monitoring data on the overburden and the bedrock wells.

The vertical hydraulic gradient between the deep and the shallow bedrock zones is monitored on a monthly basis (see Table 4-5). The vertical gradient has been observed to vary both laterally across the facility and seasonally in the three well pairs drilled on the plant and over the 18-month period in which the head differential in these zones

Table 4-6

WATER LEVEL ELEVATIONS IN OVERBURDEN PIEZOMETERS

	Surface Elevation	5/6/82	6/30/82	7/30/82	9/20/82	10/27/82	11/19/82	12/22/82	1/24/83	2/22/83	3/21/83	4/21/83	6/3/83
B-10S	616.52	611.43	606.98	603.32	602.63	Dry	603.22	Dry	607.97	611.70	615.04	616.72*	610.3
B-11S	615.43	609.81	607.51	603.10	600.52	597.10	597.72	602.15	606.83	610.75	611.91	612.78	608.9
B-13S	614.16	609.50	605.94	603.02	599.03	--	596.83	601.46	606.96	610.81	612.34	612.91	609.0
B-17S	613.70	610.54	603.74	605.70	--	--	--	--	--	--	--	--	--
B-18S	614.47	609.60	607.80	603.48	600.64	--	601.37	603.15	607.97	611.40	612.20	612.79	609.6

*Above surface elevation in standpipe.

has been monitored (see Figures 4-5 through 4-8). (Note: the three deep wells were not drilled until the summer of 1988). The vertical gradient on the east side of the site (between B-6M and B-20M) is only slightly downward in the spring and close to zero in winter. The vertical gradient in the center of the site (at B-8M and B-18M) has consistently been downward, whereas the gradient in the southwest corner of the site (B-13M and B-19M) was downward in the winter and upward, with a head differential as much as 10 feet, in the spring.

These vertical gradients are most likely a result of the manner in which the Lockport Dolomite in the Niagara Falls area recharges as well as an expression of the interconnectedness of fractures. Infiltration rates through the silt- and clay-rich overburden is quite slow. Although the source of nearly all the recharge to the bedrock aquifer is precipitation, it occurs predominantly by direct influx to the bedrock water-bearing zones at outcrops several miles upgradient. Although no consistent vertical gradient trend has been observed across the site, it is suspected that deep wells that intersect more fractures will show upward vertical gradients during periods of high recharge. For example, both B-19M and P-2 have significant upward gradients in the spring. Both wells likely have excellent fracture interconnectivity as was demonstrated by their substantial drawdown (1.31 feet for B-19 and 2.12 feet for P-2) during the full-scale P-3 pumping test.

Groundwater from the facility flows radially toward the south, southwest, southeast, and east (see Plate 2). Most groundwater flows toward the south and southwest. In April 1990, the lateral hydraulic gradient to the east was 0.003 foot/foot (ft/ft) and to the south and southwest was 0.014 ft/ft. As evidenced by the substantially higher hydraulic gradient to the south and southwest, a change in hydraulic properties has been observed in the southwest corner of the Carborundum facility, across the "hydraulic boundary" (see Figure 4-5 and Plate 2.) Water level fluctuations and the response to pumping of P-2 or P-3 are different in this area relative to the rest of the facility. The hydrogeologic data collected over the past 5 years of studies on the Carborundum plant indicate the shallow bedrock aquifer southwest of this boundary is in poor hydraulic communication with the shallow bedrock aquifer over the rest of the study area. It appears as if the shallow bedrock zone may be less highly fractured and have a lower transmissivity southwest of this boundary than the bedrock under the majority of the plant. However, as evidenced by the fact that B-19M is in good hydraulic communication with P-3, the hydraulic barrier does not extend beneath approximately 40 feet from the surface.

One possible explanation for the poor hydraulic connection to the southwest is the existence of biostromes (poorly organized, laterally extensive, ancient reefs) in the shallow bedrock interval. Biostromes are common in the Oak Orchard member of the Lockport which makes up the shallow bedrock aquifer beneath the Carborundum facility. They have also been observed in the nearby quarry. Because these depositional features lack any internal bedding, they may also be less fractured and consequently less transmissive than the surrounding bedrock. A potential biostrome interval was observed in the core of well B-19M at a depth of 38.9 to 40.5 feet below the surface. This unit was about 2 feet thick as observed in the core. However, if this unit increased in thickness laterally, as is characteristic of biostromes, it could potentially result in a hydraulic barrier.

An alternate explanation (which also may exist in conjunction with a biostrome) is that the highly fractured and transmissive zone directly beneath the Carborundum facility is due to localized weathering and does not extend beyond this boundary. Based on the data collected, it appears as if groundwater and contaminants do migrate across this boundary but at a reduced rate. The boundary does not constitute a complete hydraulic barrier. However, the hydraulic properties of the aquifer beyond this boundary have not been tested.

The salient features of the hydrogeology of the aquifers beneath the Carborundum facility can be summarized by the following:

- o The direction of groundwater flow is to the southwest, south, southeast, and east. The predominance of flow, however, is to the south and southwest.
- o The overburden is 8 to 25 feet thick and partially saturated;
- o The overburden is composed primarily of silt and clay and is a saturated aquitard rather than an aquifer;
- o Migration rates through the overburden are slow;

- The upper 10 to 20 feet of the bedrock are more highly fractured than the deeper bedrock interval;
- Groundwater flow through the upper bedrock is predominantly controlled by bedding plane fractures;
- A conjugate vertical fracture system may also trend through the area providing conduits for flow between bedding plane fractures and for limited deeper migration. These are secondary to the bedding plane fractures;
- The vertical gradient from shallow to deeper zones within the bedrock aquifer varies laterally and seasonally across the area;
- The vertical gradient from overburden to the bedrock appears to be upward in the late winter and spring and downward in the fall;
- The interconnectedness of the bedrock fracture system beneath the Carborundum facility controls the rate and, in part, the direction of groundwater flow; and
- The southwest corner of the facility exhibits different hydraulic properties than those of the rest of the study area. This may be caused by a biostrome or by the localized nature of the highly transmissive zone beneath the plant.

4.3 MIGRATION PATHWAYS

Compounds which have been released onto the surface or into the subsurface from potential source areas will eventually migrate downward through the unsaturated and saturated zones in the overburden to the bedrock groundwater, and finally through the groundwater to downgradient areas off site.

Chlorinated organics originating near the surface must migrate through the unsaturated zone to the saturated zone in the overburden before reaching the bedrock aquifer. The overburden soils are clay rich and of low permeability. Lateral migration through this zone is anticipated to be minimal. Studies on chlorinated solvents have shown that the source plume will tend to flow vertically through the unsaturated zone over a fairly restricted area until it reaches the water table, where it becomes slightly more dispersed and begins to flow according to the hydraulic properties of the saturated matrix (Schwille 1988).

Infiltration of precipitation then drives the chlorinated organics downward. This process and the rates and directions of flow through the overburden are discussed in greater detail in Section 4.5.

Because of the low permeability of the overburden soil, a minor fraction of the surface contamination may migrate away from the source area with runoff from precipitation, rather than infiltrate the surface soil. However, runoff on the site is minimal because of the low surface slopes. What surface runoff does occur will be collected in the drainage ditches and storm sewers designed for this purpose which presently discharge to the Niagara County Sewer District publicly owned treatment works (POTW). (Loading to the POTW will be presented in Section 4.5.7.) Formerly, chlorinated organics may have entered Cayuga Creek from the SPDES outfall. However, the outfall has been inactive for years and, as such, is not regarded as a principal migration route.

A sand and gravel zone was encountered at the base of the overburden, immediately above bedrock, in some of the borings drilled on the site. Chlorinated organics would tend to migrate quite readily along such an interval. However, as previously noted in Section 4.2.2, these gravel zones are discontinuous, minimizing long-distance migration.

Once chlorinated organics have moved downward through the overburden, they migrate into the highly fractured and weathered zone at the top of the bedrock. Lateral migration through the upper bedrock zone is the predominant and fastest route of contaminant migration to downgradient areas. The deeper bedrock zones are more massive and less fractured than the upper 10 to 20 feet of the Lockport Dolomite. Only in zones where vertical fractures produce avenues for downward migration is there significant flow to the deeper bedrock. The vertical hydraulic gradient between the shallow and the deep bedrock is quite complex beneath the Carborundum facility, as noted in the earlier discussion of the site hydrology. It appears to change laterally across the site and to vary seasonally. Chlorinated organic concentration patterns are a better indication of the predominant avenues of transport from the shallow to the deeper bedrock zones than are vertical gradients. The comparatively low concentrations of chlorinated organics in the deeper bedrock wells suggest minimal vertical flow to deeper bedrock zones is occurring beneath the facility.

Regional groundwater flow through the upper bedrock in the City of Niagara Falls area has been redirected by the twin conduits and reservoir of the Niagara Power Project built in 1958-1962 (see Figure 2-3). In the vicinity of the Carborundum plant, groundwater flows to the south and southwest toward the Niagara River (4.5 miles away). Local groundwater flow in the shallow bedrock, as shown in Figures 4-5 through 4-8, and in Plate 2, is also to the southwest over the majority of the study area. However, a groundwater high trending northwest-southeast extends across the center of the plant. Consequently, in the northeast, groundwater flows toward the east or the east-southeast before turning to the south.

The nearest two surface water bodies which are generally downgradient of the facility are Cayuga Creek and the Niagara River. Cayuga Creek, located about 2,000 feet east of the facility, flows south, parallel to Walmore Road, before turning east and then generally south toward the Niagara River (see Figure 1-1). The elevation of surface water for Cayuga Creek along Walmore Road ranges from 610 to 615 feet above sea level. The projection of the potentiometric surface of groundwater from the facility which may flow toward this area is about 605 feet above sea level or 5 to 10 feet beneath the elevation of surface water in Cayuga Creek. This projection is estimated from groundwater data from B-31M, which is located about 200 feet from Cayuga Creek, during the spring of 1990, a period when seasonal groundwater elevations were very high due to record precipitation. Projected groundwater elevations are similar enough to the elevation of Cayuga Creek to suspect that shallow groundwater could discharge into the creek. Some potential exists for low levels of chlorinated organics being discharged into the creek as groundwater in B-31M contains low levels (less than 10 ppb) of TCE and 1,2-DCE. However, surface water and sediment sampling from the creek was found to contain no chlorinated organics which are attributable to the facility. Thus, it is concluded that chlorinated organics from the facility are not discharging into Cayuga Creek at quantifiable levels.

The Niagara River, which is located 4.5 miles south-southwest and downgradient of the facility, is a potential distant discharge area for groundwater which flows beneath the Carborundum facility. Groundwater sampling, as discussed in Section 4.4.3, has been performed at three potential receptors which are immediately downgradient of the facility to the southwest. No chlorinated organics that are attributable to the facility have been found at any of these locations. Thus, it can be concluded that the groundwater plume appears to disperse and degrade to non-detectable levels to the southwest of the facility, negating any potential effect on the Niagara River much further downgradient.

Groundwater, flowing to the southwest on the west end of the Carborundum facility, may turn and flow due west toward the quarry which lies 0.6 mile west-southwest of the plant. This presumption has not been verified by actual measurements in water elevations and potentiometric surface maps but rather is based on the general principle that groundwater flows to the area of lowest head. Since the dry quarry bottom is at least 50 feet below the water table at the Carborundum facility, it appears to be a potential local sink for groundwater flow. However, there may be no hydraulic connection between the aquifers beneath the Carborundum plant and the quarry. Estimates of the hydraulic conductivity of the quarry area from the average volume pumped per day to keep the quarry dry and the exposed surface area of the quarry walls suggest that the quarry area is less transmissive than the bedrock beneath the Carborundum plant.

The additional monitoring wells which have been installed to the southwest of the Carborundum facility provide support for the presumption that the quarry may not be in hydraulic connection with the aquifer beneath the plant. These wells show a continued hydraulic gradient to the southwest rather than to the west. In addition, well B-28M, located 1,040 feet to the west of the facility boundary and in a direct line between the facility and the quarry, has yielded no chlorinated organics during the two rounds of sampling since its installation indicating that groundwater is flowing from the facility principally toward the southwest rather than the west.

4.3.1 Bedrock Aquifer Properties

The hydraulic properties of the aquifer control the rate of groundwater flow. These properties were evaluated by two pumping tests conducted on the site, one at P-2, the plant production well, and one at

P-3 drilled specifically for aquifer testing. The results of these tests have been detailed in a published E & E report (December 1986) for the test on P-2 and in a letter report (May 1989) for the test on P-3. The complete raw data and analytical plots from these tests are presented in Appendix B. The hydraulic parameters derived from these studies and other published regional studies are summarized in Table 4-7.

In general, both tests showed the local bedrock aquifer beneath the Carborundum facility to have higher transmissivity than reported values for the shallow Lockport Dolomite in the Niagara Falls area (Johnston 1964). The relatively high maximum production rate (372 gpm) attained in the plant supply well P-2 during the 1986 test is indicative in itself of the above average yield of this local area. (Typical yields in the upper Lockport are no more than 50 to 100 gpm.) Curve matching and Jacob-straight-line techniques applied to the data collected in 12 to 16 observation wells monitored during each test resulted in average transmissivities of the upper bedrock on the order of 25,000 to 35,000 gpd/ft. Average aquifer hydraulic conductivities for the shallow bedrock for the P-2 pumping test were 2,390 gpd/ft^2 (0.11 centimeters per second [cm/s]), and for the P-3 test, 1,990 gpd/ft^2 (0.09 cm/s). Optimum storage capacity calculations provided storativity estimates on the order of 0.007 to 0.017. P-2 was pumped at 372 gpm during the 24-hour December 1986 test. P-3 was pumped at its maximum obtainable yield of approximately 95 gpm during the 38-hour April 1989 test.

After both tests, 100% recovery to pretest static equilibrium levels was not observed. Similar recovery test responses occurred in other pumping tests conducted in the Lockport Dolomite in the Niagara Falls area (Johnston 1964). These slow recoveries may be attributed to a lack of sufficient recharge via vertical flow from the overburden or from insufficient lateral flow within the bedrock beyond the local area, or from both phenomena. It is known that the overburden is very clay rich, and recharge through this zone is quite slow. Therefore, inadequate flow volumes are available through this pathway. However, as stated in the earliest section on the local hydrogeology, most of the regional recharge to the bedrock aquifer is from lateral flow from upgradient source areas. Insufficient recharge may be available from

Table 4-7

SUMMARY OF HYDROGEOLOGIC PARAMETERS

Unconsolidated Overburden Deposits		
Depth to the water table	0-18 ft.	
Average thickness of the overburden	15.5 ft.	
Hydraulic conductivity of lake clays and silts	0.04 gpd/ft^2	(1)
Hydraulic conductivity of glacial till	23.0 gpd/ft^2	(1)
Shallow Bedrock Aquifer		
Depth to the water table	0-28 ft.	
Average thickness of shallow fractured zone	10-20 ft.	
Average hydraulic conductivity calculated for area surrounding P-2 (assuming b = 10 ft.)	2,390 gpd/ft^2	(2)
Average storage coefficient calculated for area surrounding P-2	.007	(2)
Average hydraulic conductivity calculated for area surrounding P-3 (assuming b = 15 ft.)	1,990 gpd/ft^2	(3)
Average storage coefficient calculated for area surrounding P-3^3	0.0170	(3)
Average hydraulic conductivity for 4 tests of upper 17 to 42 feet of the Lockport Dolomite	26.7 gpd/ft^2	(1)
Regional average hydraulic conductivity for upper 110 to 140 feet of the Lockport Dolomite	20.9 gpd/ft^2	(1)

[AD]CZ4140:D2467, #2365, PM = 24

(1) Values from Johnston 1964.
(2) Values from December 1986 pumping test on P-2.
(3) Values from April 1989 pumping test on P-3.

these upgradient sources as well, if flow through these upgradient areas cannot keep pace with flow rates close to the pumping well. This causes the dewatered area or volume of aquifer after termination of the pumping test to recharge more slowly than it dewatered. During the P-3 pumping test, the pattern observed in the drawdown data on B-27M indicated the presence of a nearby hydraulic boundary. This apparent boundary may be caused by a nearby zone of lower transmissivity. This lower zone of transmissivity which, as previously mentioned, is more characteristic of the Lockport Dolomite than the transmissivity observed in the site area, results in a slower recharge rate than the dewatering rate. This conclusion is also verified by the fact that neither pumping test produced a steady-state condition (i.e., aquifer recharge equaled discharge). Groundwater elevations in the aquifer were still being drawn down at the termination of both tests. Most likely this is because the site area has abnormally high transmissivity which results in higher dewatering rates than can be sustained outside the site area; thus, the aquifer continues to draw down and does not reach a steady state condition.

As noted in Section 4.2.2 on the hydrogeology beneath the Carborundum facility, it appears as if the area to the southwest may have lower transmissivity than the aquifer directly beneath the plant. This area may have similar hydraulic properties to those of the locations summarized by Johnston (1964). Comparisons of the hydraulic parameters of bedrock wells presented in Johnston's report and those estimated from the two pumping tests conducted on the plant (see Table 4-7) show the Carborundum area to be have a higher than average hydraulic conductivity. Johnston reported transmissivity estimates between 330 and 68,000 gpd/ft for the Lockport (to depths up to approximately 150 feet) which convert to hydraulic conductivity estimates of 8 to 500 gpd/ft^2. Pumping test results for the shallow Lockport beneath the Carborundum facility indicate the local bedrock beneath the plant has an average hydraulic conductivity of 1,990 to 2,390 gpd/ft^2.

The concept that the Carborundum facility lies in a localized and spatially limited, high transmissivity zone of the Lockport Dolomite agrees with Yaeger and Kappel's hypothesis (USGS 1987) that a northeast trending zone of high transmissivity cuts across the Niagara Falls area.

However, this hypothesis is based on sparse hydrological data which includes only the Carborundum facility's anomalously high transmissivity and hydraulic conductivity (reported in previous studies) and a zone of high yielding wells near the Niagara River. There is no strong regional indication that these two areas are connected by a continuous zone or that this hypothesized northeast vertical fracture trend has a local expression across the Carborundum plant.

While vertical fractures have been observed from cores in monitoring wells on the site, they do not seem extensive enough to provide evidence that the facility lies within a large-scale vertical fracture zone. In particular, the comparably low levels of chlorinated organics observed in deep monitoring wells B-18M, B-19M, and B-20M indicate that vertical fractures do not, in general, extend to the deeper portion of the aquifer, which is contrary to what would result if a large-scale vertical fracture zone intersected the facility area.

The Carborundum facility lies in an area of higher than average hydraulic conductivity and transmissivity than is characteristic for the Lockport aquifer. Core examination and monitoring data of deep groundwater from the site indicate that this anomaly lies within the shallow weathered bedrock portion of the aquifer and is most likely not influenced by a large-scale vertical fracture zone.

The capture area from wells P-2 and P-3 is depicted in Figures 4-9 and 4-10. It is obvious from these figures that an effective groundwater capture zone to eliminate further off-site migration can be established by pumping these two wells in unison. The maximum necessary rate to establish this zone will be about 300 gpm. However, it is possible that much lower rates will be sufficient to establish an effective capture area for containment and remediation of chlorinated organics in the groundwater beneath the facility. This conclusion is supported by consideration of the above average hydraulic conductivity and transmissivity of the shallow Lockport Dolomite that underlies the source areas of the Carborundum facility and the fact that long-term groundwater recharge into the facility area will most likely not be able to keep pace with the high extraction rates observed during the P-2 and the P-3 pumping tests. If this relationship occurs, a lower rate will result in a sufficient capture area to remediate the source areas.

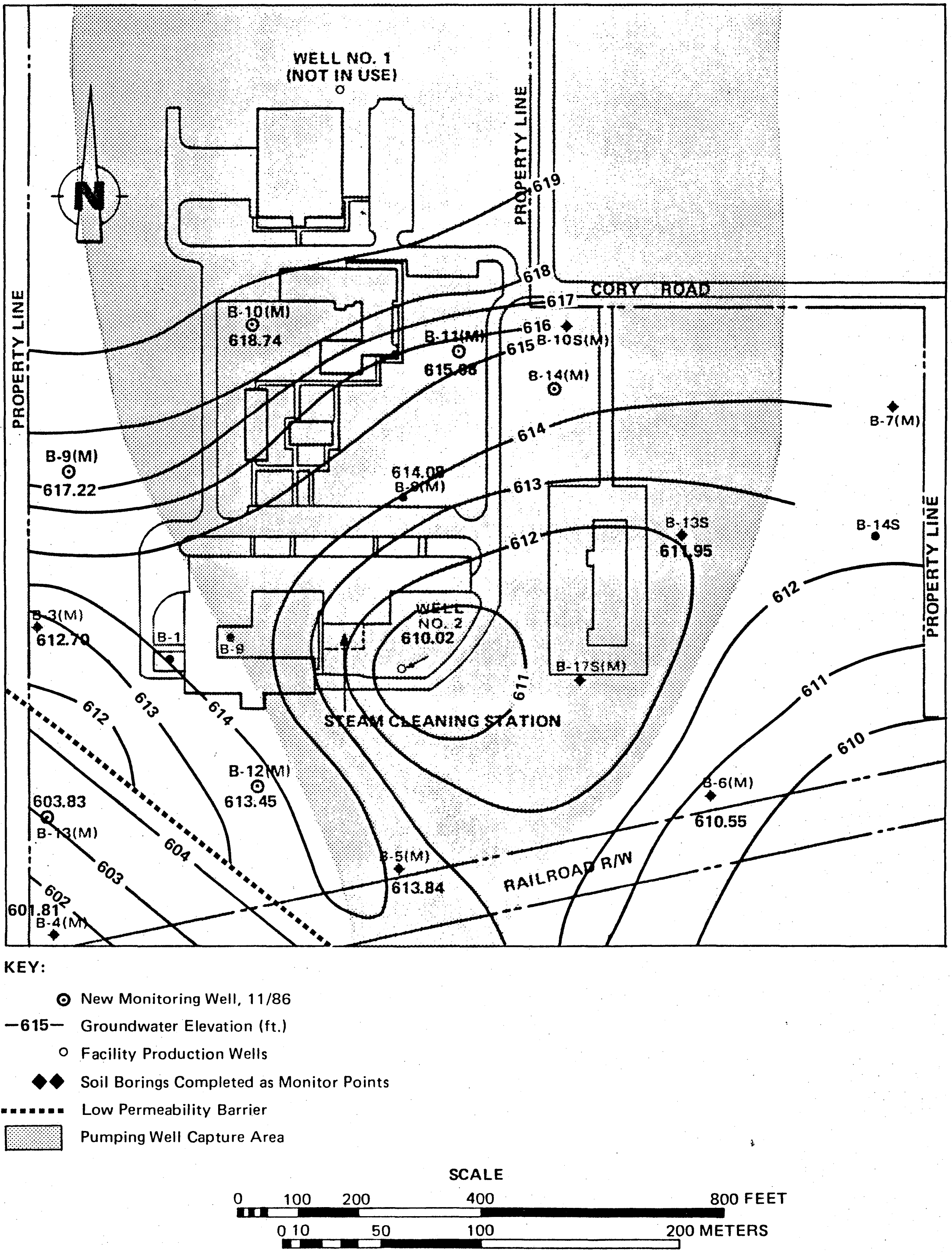

Figure 4–9
ESTIMATED GROUNDWATER ELEVATION AND WELL CAPTURE AREA AFTER PUMPING P-2 AT A RATE OF 200 gpm FOR 24 HOURS

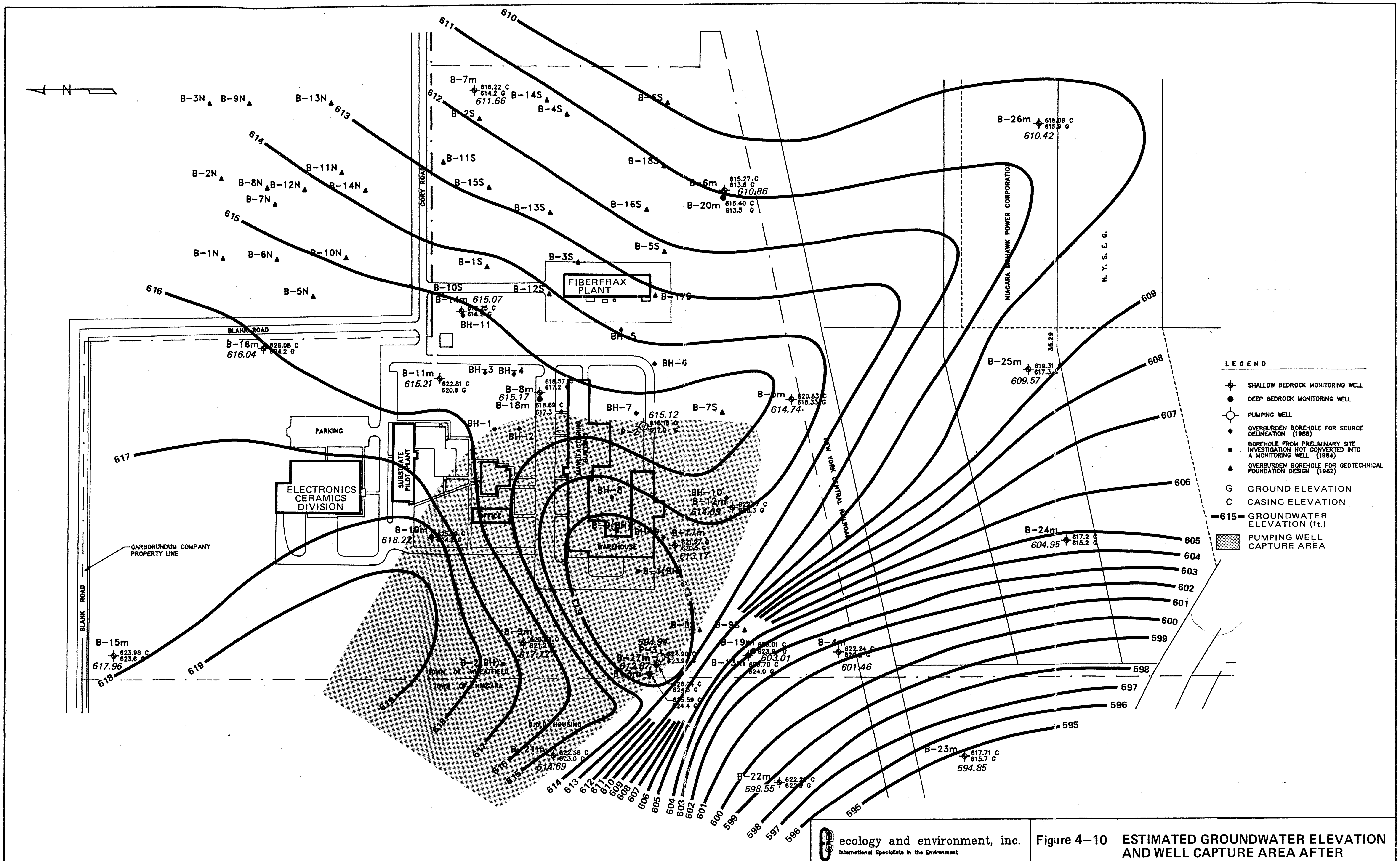

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Figure 4—10 ESTIMATED GROUNDWATER ELEVATION AND WELL CAPTURE AREA AFTER PUMPING P-3 AT A RATE OF 90 gpm FOR 38 HOURS

SCALE	DATE ISSUED	C.A.D. FILE NO.	DRAWING NO.	REV.
1" = 100'		CZ2MWLOC		

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4.4 OBSERVED ZONES OF CONTAMINATION

The two source areas of highest concentration on the facility apparently resulted from chlorinated organics migration from the surface close to the southwest corner of the manufacturing building and from subsurface buried septic system tank contributions northeast of the manufacturing building. In these areas, shallow bedrock groundwater exhibits the highest concentrations of chlorinated organics.

In general, the deeper groundwater zones and the surface soil samples do not contain high levels of chlorinated organics. The only chlorinated organics in near-surface soils were found in the courtyard. The only chlorinated organics found in the deep bedrock wells occurred downgradient of the suspected hydraulic boundary at B-19M in the southwest corner of the study area.

4.4.1 Chlorinated Organics in the Overburden Soils

The soils in the overburden were sampled on two occasions, once in 1984 (boreholes B-1(BH) to B-9 (BH), see Table 4-1) and once during 1986 (boreholes BH-1 to BH-11, see Table 4-2). Boreholes B-3(BH) to B-8(BH) were converted to monitoring wells B-3M to B-8M. The samples taken from the borings drilled in 1984 were analyzed using only a screening method which quantitatively measured TCE and semi-quantitatively measured carbon tetrachloride, chloroform, and 1,1,2,2-tetrachloroethene. Three of these nine borings contained these compounds. They included one sample just outside the southwest corner of the manufacturing building, one sample in the manufacturing building courtyard, and one sample near the buried septic system tanks north of the manufacturing building. The highest levels of chlorinated organics were in the 8- to 10-foot interval. The concentrations detected ranged from 0.03 to 10 ppm of TCE.

A more accurate analytical scan was run on the borehole samples taken in 1986. These samples, which were analyzed for purgeable halocarbons using EPA Method 601, were drilled in the vicinity of suspected source areas, and, consequently, chlorinated organics were found in virtually all 10 boreholes (see Figure 4-2). The compound having the highest concentration was TCE. TCE was found in four of these boreholes above 1 ppm: BH-2, BH-6, BH-8, and BH-9. The highest levels were found in the 4- to 8-foot and 8- to 12-foot depth samples in BH-2, near the buried septic system tanks, and in BH-9, southwest of the manufacturing building. The TCE at BH-9, which is suspected to have originated at the surface, was found shallower than the TCE at BH-2, which is suspected to have originated from leaking buried septic system tanks. The maximum concentrations found in these two locations was 66 ppm at BH-2 (in the 8- to 12-foot interval) and in BH-9 (in the 4- to 8-foot interval).

During the August 1984 and December 1986 soil sampling events, only one of the near-surface composite samples showed any chlorinated organics (other than MC) above 1 ppm. This boring, BH-8, was drilled inside the courtyard of the manufacturing building where soils containing chlorinated organics from Area A were moved to level the courtyard. DCE was found in the surface soils in the courtyard at 1.9 ppm in BH-8 (0 to 4 feet). This DCE probably came from the soils transported from Area A, since DCE was also found at 3.8 ppm in the soils near B-17M (BH-9 at 4 to 8 feet) and at a maximum of 170 ppm in the groundwater at B-17M.

The most widespread compound found in these borings was MC. MC was found in all 10 site borings above 1 ppm and in six of the 10 borings above 20 ppm. The highest level of MC found was 63 ppm in the 4- to 8-foot interval in borehole BH-3. The depth of maximum MC contamination in six of the 10 borings was within the 8- to 12-foot interval. In the remaining borings, the maximum MC concentration was found in the 4- to 8-foot interval or between 12 to 16 feet. No uniform trend of increasing or decreasing concentration with depth was observed.

Chloroform, DCA, 1,1-DCE, 1,2-DCE, 1,1,1-TCA, and VC were also found in many of the borings. Of these compounds, only 1,2-DCE was found at concentrations greater than 1 ppm.

In July 1989, three soil samples were collected from the inactive SPDES outfall on the facility and between the facility's eastern boundary and Cayuga Creek to determine if the inactive outfall contained high levels of chlorinated organics. Sediment and surface water samples were collected at two locations immediately upstream and downstream of the confluence of the inactive SPDES outfall and Cayuga Creek (see Figure 3-5). MC, cis-1,2-DCE, TCE, and 1,1,1-TCA were found in the sediment samples collected from the outfall. The concentration of each chlorinated organic found in the samples decreases with increasing distance from the site (see Appendix C, Table C-13). The highest concentrations of MC (5,400 ppb), cis-1,2 DCE (4,300 ppb), and TCE (4,020 ppb) were found in sample SD-1, which was collected closest to the suspected source areas discussed in Section 4.1. With the exception of MC, relatively low levels of TCE (72 ppb) and 1,1,1-TCA (48 ppb) were found in sample SD-3, which was obtained about midway between the facility boundary and Cayuga Creek. Low levels of chloroform (0.77-73 ppb) were found in both sediment and surface water samples collected from Cayuga Creek. Relatively low levels of MC (4.95-370 ppb) were found in both surface water samples and one sediment sample from Cayuga Creek.

Shallow subsurface soil samples were collected from the SPDES outfall in January 1990 to determine if high levels of chlorinated organics were present in the shallow subsurface. Potentially, they could be mobilized if the SPDES outfall was reactivated to discharge treated groundwater during remediation. Samples were collected at five locations at a depth of 6 inches and 3 feet (see Figure 3-5). Only sample S-1 yielded significantly elevated levels of chlorinated organics. Sample S-1, collected at a depth of 3 feet, yielded TCE at 13.9 ppm and 1,2-DCE at 0.32 ppm (see Appendix C, Table C-14). The 6-inch sample at the same location contained TCE at 1.39 ppm and 1,2-DCE at 0.27 ppm. These levels correspond closely to Sample SD-1 which was collected in the same vicinity in July 1989. Both samples SD-1 and S-1 were collected within the boundary of the Carborundum facility. All other samples collected during this second sampling event were near or below detection limits.

Comparisons of all samples from both Cayuga Creek and the SPDES outfall which contain MC and chloroform to trip blanks and laboratory rinsate blanks indicate these chemicals resulted from laboratory or field interferences. Sediment samples were compared to instrument level concentrations to draw this conclusion.

The SPDES outfall sampling indicates that elevated levels of TCE and 1,2-DCE are present in the outfall and appear to decrease in concentration with increasing distance away from the facility. The Cayuga Creek sampling indicates that the chlorinated organics that remain in the sediment of the inactive SPDES outfall are not migrating into Cayuga Creek.

A well point, a temporary stainless-steel monitoring well, was installed immediately adjacent to the sanitary sewer line along Cory Road north of B-14M. The purpose of the well point was to sample groundwater in the sewer line gravel bed to determine if chlorinated organics may be moving preferentially through the gravel. Potentially high levels of chlorinated organics could move along the gravel bed because the facility sanitary sewer line runs along a source area in the vicinity of B-8M. Groundwater was encountered at about 3 feet beneath the surface during the installation and sampling of the well point. The gravel bed was encountered at about 10 feet beneath the surface. Thus, groundwater was in contact with the gravel bed during sampling.

Four chlorinated organics were detected from the groundwater sample collected from the well point. These include chloroform, 1,1,2,2-tetrachloroethane, cis-1,2-DCE, and TCE (see Appendix C, Table C-13). Chloroform and 1,1,2,2-tetrachloroethane were detected at levels below 2 ppb and are regarded to be insignificant. Cis-1,2-DCE and TCE were detected at 15.9 ppb and 261 ppb, respectively. These concentrations are less than average concentrations found in the chlorinated organic plume in this area. For instance, the average concentration of 1,2-DCE and TCE for quarterly samples from well B-14M (the nearest monitoring well to the well point) are 58 ppb and 3,761 ppb, respectively. Both of these average concentrations exceed the level of 1,2-DCE and TCE found in the well point. In particular, the level of TCE is an order of magnitude less than the average level in B-14M. These data indicate that the gravel bed does not provide a preferential avenue for chlorinated organic movement off the facility.

A soil gas survey was performed in late April and early May of 1990 at the DoD facility which borders the western boundary of the Carborundum plant (see Figure 4-11). The purpose of the survey was to determine the potential impact to residents living at the DoD, if any, that could result from chlorinated organics partitioning from groundwater into soils and then into ambient air. Forty-seven samples were attempted during the survey. Sufficient airflow was established in 25 locations to sample soil gas. No flow occurred at 22 sample locations

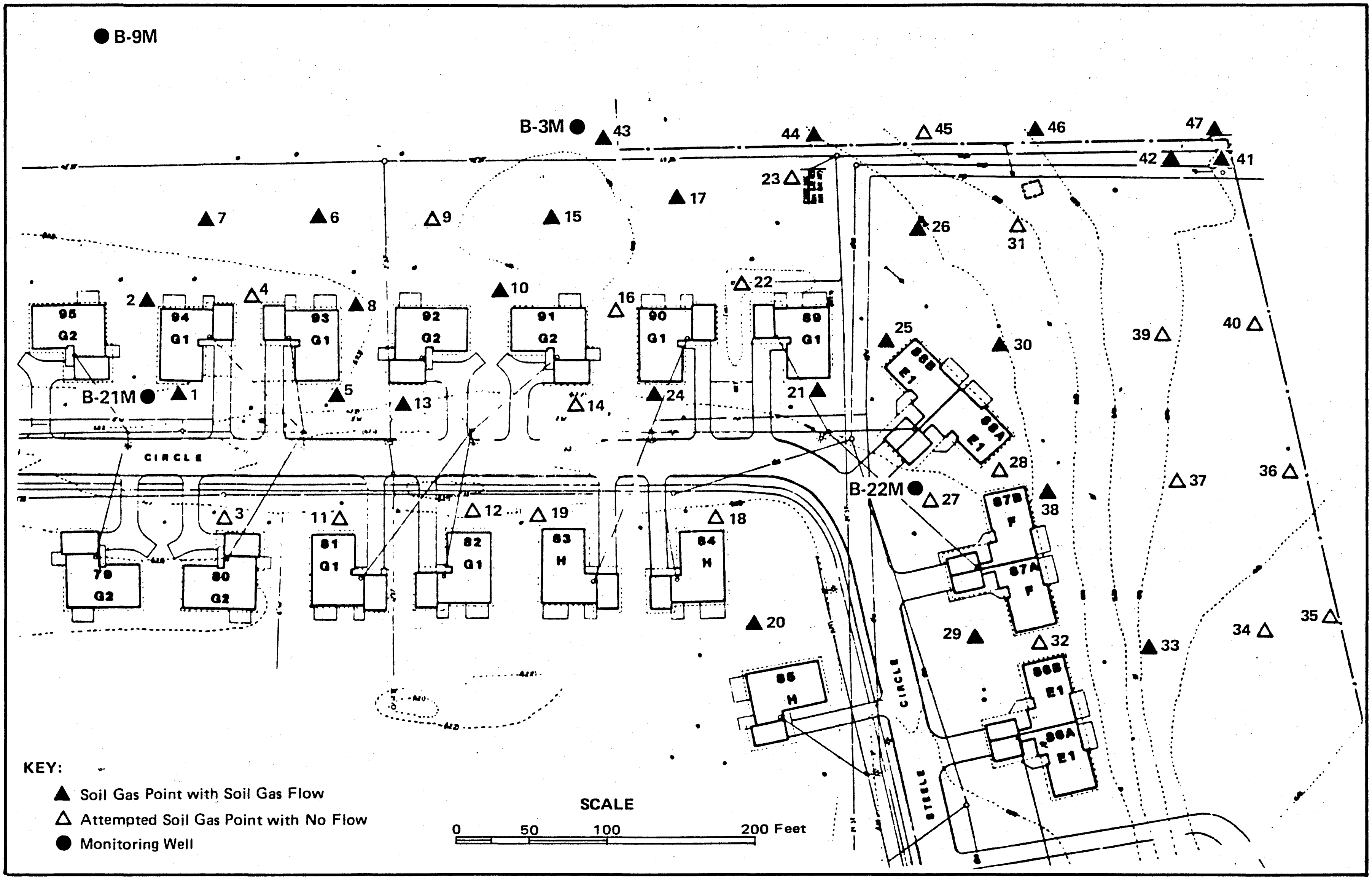

Figure 4–11 SOIL GAS SURVEY POINTS AT DoD FACILITY (4/90)

due to the low permeability of the soils in this area. The first 16 samples of the survey had to be repeated because the integrator was not run long enough to determine if TCE was present in the soil gas. These samples were repeated for TCE only as the other compounds had previously been analyzed during the initial sampling. An OV-101 column was used for the second run of the first 16 samples. This column had a faster run time for TCE (3 minutes) than the SP-1000 column which had a run time of 14 minutes. The remaining samples, after the first 16, were run for a full 14 minutes to include TCE. Results of the soil gas survey are presented in Appendix C, Table C-15.

Of the 25 locations where sufficient air flow was established to obtain a soil gas sample, only one sample location, Sample 26, contained soil gas at levels above detection limits (see Figure 4-11 and Table 4-8). Slightly higher levels resulted from the second sampling (Sample 26A) at this location. These levels were 8 µg/L of 1,2-DCE, 2 µg/L of TCE, 1 µg/L of VC, 4 µg/L of 1,1-DCE, 0.6 µg/L of TCA, and 0.2 µg/L of of 1,1-DCA. Sample 26 is located near the boundary of the Carborundum plant and the DoD facility. The sample is about 200 feet from the nearest residence in the DoD subdivision.

One potential concern regarding the data from the soil gas survey was if there was an adequate number of samples collected to verify that there was no risk to DoD residents. As mentioned previously, 25 successful samples were collected out of 47 sample locations attempted. The vast majority of these 25 samples were obtained in and around homes nearest the Carborundum plant. In particular, Samples 43, 17, 44, 26, 46, 42, 41, and 47 were obtained near or at the boundary of the plant in an area where maximum levels of chlorinated organics in the downgradient plume are suspected to exist. Only Sample 26 in this area had levels above detection limits. Sample 26 is surrounded by Samples 25, 30, 44, and 46, all of which were below detection limits. Thus, it is concluded that the sampling frequency was sufficient to adequately characterize soil gas within the DoD facility and that the amount of chlorinated organics present in soil gas in this area is negligible. (This data will be considered further in the risk assessment.)

Table 4-8

ANALYTICAL RESULTS OF SOIL GAS SAMPLES AT DoD FACILITY WITH LEVELS ABOVE DETECTION LIMITS (results in μg/L)

Sample Number	Depth	MC	1,1-DCE	1,1-DCA	1,2-DCE	TCA	TCE	VC
26	3.5 ft	<0.002	3	0.1	2	0.3	NA	0.1
26A	3.5 ft	<0.003	4	0.2	8	0.6	2	1

[AD]CZ4140:D2467, #3399, PM=18

NA = Not analyzed.

4.4.2 Chlorinated Organics in the Bedrock Aquifer

Groundwater in the shallow bedrock aquifer beneath the Carborundum facility contains TCE, TCA, carbon tetrachloride, and many of their degradation products and/or impurities including 1,2-DCE and VC from TCE; DCA from TCA; and chloroform and possibly MC from carbon tetrachloride. MC was found in a fairly evenly distributed pattern in nearly all the monitoring wells rather than just in the restricted area where carbon tetrachloride was found. This suggests the MC did not originate from the carbon tetrachloride. Trichlorofluoromethane was analyzed on a one-time basis in the July 1989 sampling round. However, none of the samples contained this compound.

The most prevalent compounds which are present in groundwater are TCE and its two most prevalent degradation products, 1,2-DCE and VC. Since January 1989, analysis of 1,2-DCE has been subdivided into the cis-and-trans isomers. These analyses have indicated that 95 to 99% of the 1,2-DCE present in groundwater is the cis-isomer.

The highest level of chlorinated organics found in the shallow bedrock aquifer to date was 170 ppm of TCE in B-8M (February 1988), 160 ppm TCE in B-17M (November 1988), and 170 ppm 1,2-DCE in B-17M (November 1988). B-8M and B-17M are screened beneath the two most prominent source areas. The maximum concentrations of the other compounds detected to date are as follows:

VC = 26,000 ppb B-17M (December 1988)

TCA = 3,700 ppb P-2 (October 1987)

MC = 2,300 ppb B-17M (December 1988)

DCA = 1,200 ppb P-2 (October 1987)

1,1-DCE = 580 ppb B-17M (November 1988)

Carbon Tetrachloride = 460 ppb B-8M (April 1989)

Chloroform = 180 ppb B-8M (October 1986)

PCE = 9.9 ppb B-11M (January 1989)

Depth-specific groundwater samples were collected in July 1989 from the bottom of monitoring wells B-8M and B-17M to determine if chlorinated organics were present in groundwater as a dense non-aqueous phase liquid (DNAPL). These wells were selected because they contain the highest levels of chlorinated organics in groundwater at the facility and because they are screened in groundwater beneath overburden source areas. MC, cis- and trans-1,2-DCE, 1,1,1-TCA, TCE, and VC were present in groundwater from these wells. However, the concentrations of chlorinated organics were comparable to levels measured on a quarterly basis and were in all cases well below the solubility of the various chlorinated organics found (see Appendix C, Table C-13). For instance, the solubility of TCE is 1,100,000 ppb whereas the levels of TCE found in B-8M and B-17M were 43,700 ppb and 21,200 ppb, respectively. Similar comparisons between solubilities and measured concentrations of the other chlorinated organics were observed.

From quarterly groundwater sampling, insignificant levels of chlorinated organics were found north of the substrate pilot plant, directly east of the main plant, and northeast of the Fiberfrax plant. This is as would be expected based on the location of the suspected source areas and the fact that groundwater beneath two-thirds of the facility flows to the southwest.

The deeper bedrock (greater than 20 feet into the dolomite) was sampled 40 to 50 feet into bedrock in three locations: (1) southwest of the plant buildings (B-19M), (2) southeast of the plant buildings (B-20M), and (3) close to the suspected leaking, buried septic system tanks at the center of the plant (B-18M). Only B-19M consistently contains chlorinated organics (see Table 4-3). 1,2-DCE, DCA, TCE, and TCA were all found in this well above 50 ppb in the most recent sampling event (April 1990). VC was found with a maximum concentration of 31 ppb in B-19M. Only low levels of TCE were found in well B-18M in the first two sampling rounds, but in January 1989, the levels jumped to 61 ppb, then fell back down below detection limits 3 months later. In the four quarters of sampling since April 1989, all chlorinated organics have remained below detection limits in well B-18M. DCE and MC were found on the order of 1 to 2 ppb in this well. Virtually no chlorinated organics have been found to date in B-20M.

From groundwater elevation maps, it appears that chlorinated organics originating in the center of the plant, in the vicinity of B-8M, will more readily migrate toward the east-southeast in the winter and spring of the year (see Figures 4-5 and 4-6). In the summer and fall, the groundwater high that trends southeast through the facility shifts eastward and centers on well B-8M, causing water to flow radially in three directions away from the suspected sources in the B-8M vicinity (see Figures 4-7 and 4-8). The closest downgradient well from this source area is B-6M. A maximum of 260 ppb of TCE, 64 ppb of 1,2-DCE, and 5.3 ppb of VC have been found in this monitoring well within the last year and a half. In the most recent sampling round (April 1990), TCE was only found at 88 ppb and 1,2-DCE at 9.1 ppb in this downgradient well. It appears that chlorinated organics from the central plant area may be reaching B-6M in an episodic, slug-type manner. However, by the time they have migrated the required distance from the source areas, the concentration in the plume has decreased considerably.

The plume continues to decline in concentration as it moves away from B-6M toward the south and southeast. B-26M, which is 700 feet south-southeast of B-6, has yielded TCE in only two instances at very low levels of 1.3 and 3.1 ppb. B-31M, a newly installed monitoring well in December 1989, is located 1,650 feet east-southeast of B-6M. Only very low levels of 1,2-DCE (2.7 and 2.0 ppb) and TCE (9.1 and 6.9 ppb) have been detected in groundwater from this well in the two sampling rounds since it was installed. However, in both instances, the level of TCE from B-31M exceeded the Maximum Contaminant Level (MCL) for this compound, which is 5 ppb.

TCE and its degradation products and, to a lesser degree, tca and its degradation products have been found north of the administration office and south and west of Cory Road. High concentrations of TCE, in particular, have been found in this area in the past (i.e., B-14M exhibited 7,700 ppb TCE in July 1987). Recently, however, concentrations in these areas have been decreasing. These wells lie slightly downgradient of the previously identified source areas, including Tank 8 and Tank 9 and the two leach fields near well B-8M. Most likely, the chlorinated organics in wells B-11M and B-14M are from these sources. This conclusion is further supported by comparing the chlorinated organics derived from the source area near B-8M, which is almost entirely TCE, to the chlorinated organics in B-11M and B-14M. Both B-11M and B-14M have very high ratios of TCE to 1,2-DCE and almost no

VC. This relationship is typical of the source area near B-8M where little degradation of TCE has occurred and atypical of other source areas which have a greater degree of degradation.

Isopleth maps of the April 1989 sampling data for the three compounds found most extensively in the shallow bedrock groundwater (TCE, 1,2-DCE, and VC) are presented in Figures 4-12 through 4-14. Isopleth maps for the same compounds (TCE, 1,2-DCE, and VC) from the most recent sampling data (April 1990) are presented in Plates 3, 4, and 5. These are representative examples of the approximate plume locations. The actual plumes are probably much less homogeneous and integrated than they appear in these diagrams since each mapped plume is actually made up of several plumes from a number of different sources. In addition, these isopleth maps only represent two sample dates and the plume concentrations have been observed to fluctuate seasonally as much as one order of magnitude because of episodic influx of chlorinated organics. The complexity of these plume variations with time are further discussed in Section 4.5, Fate and Transport.

Currently, the area southwest of the manufacturing building has the highest levels of chlorinated organics. TCE and some 1,2-DCE are still found in the vicinity of B-8M, but most of the groundwater plumes composed of the degradation products of TCE and TCA have been found in the southwest area of the facility and off site. In particular, VC levels of 2.6 ppb, 1,2-DCE levels of 73 ppb, and TCE levels of 2.8 ppb were detected during the most recent sampling event (April 1989) in the farthest downgradient and off-site well (B-29M).

Other chlorinated organics which are found less extensively in the bedrock groundwater beneath the facility include carbon tetrachloride and its degradation products, chloroform and MC. The carbon tetrachloride and chloroform plumes have primarily been found on the east end of the plant centered around B-8M and P-2. The maximum concentration of carbon tetrachloride detected to date was 460 ppb in well B-8M (April 1989) and the maximum concentration of chloroform was 180 ppb, also in B-8M (October 1986). MC has been found in the primary source areas of the plant at quite high concentrations in the past (1,700 ppb at B-8M in March 1985 and 2,300 ppb at B-17M in December 1988). However, MC levels have been close to or below detection limits everywhere across the site

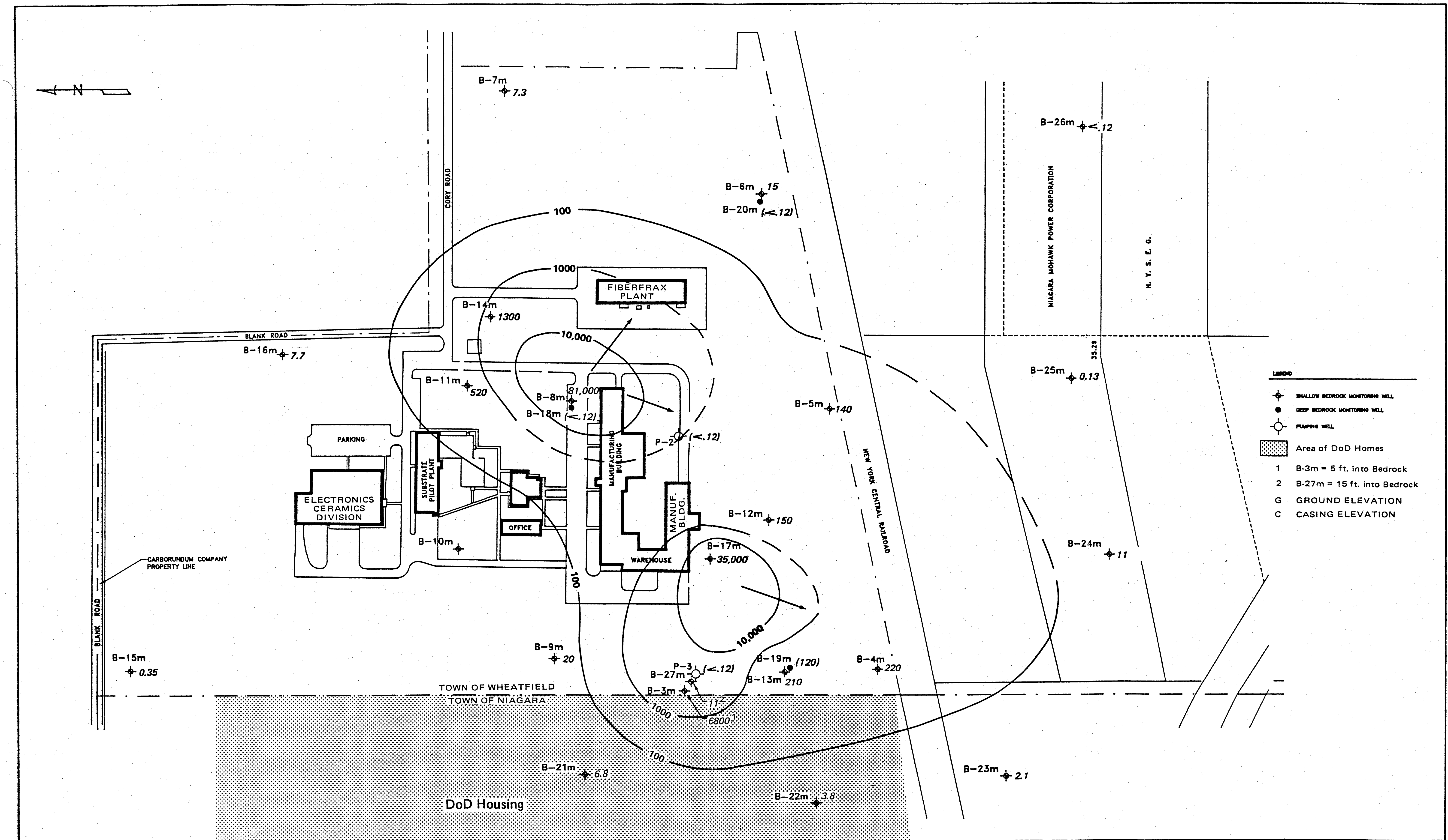

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Figure 4—12 TRICHLOROETHENE (TCE) CONCENTRATIONS (ppb) IN SHALLOW BEDROCK AQUIFER (APRIL 1989)

SCALE	DATE ISSUED	C.A.D. FILE NO.	DRAWING NO.	REV.
1" = 200'		CZ2MWLOC		

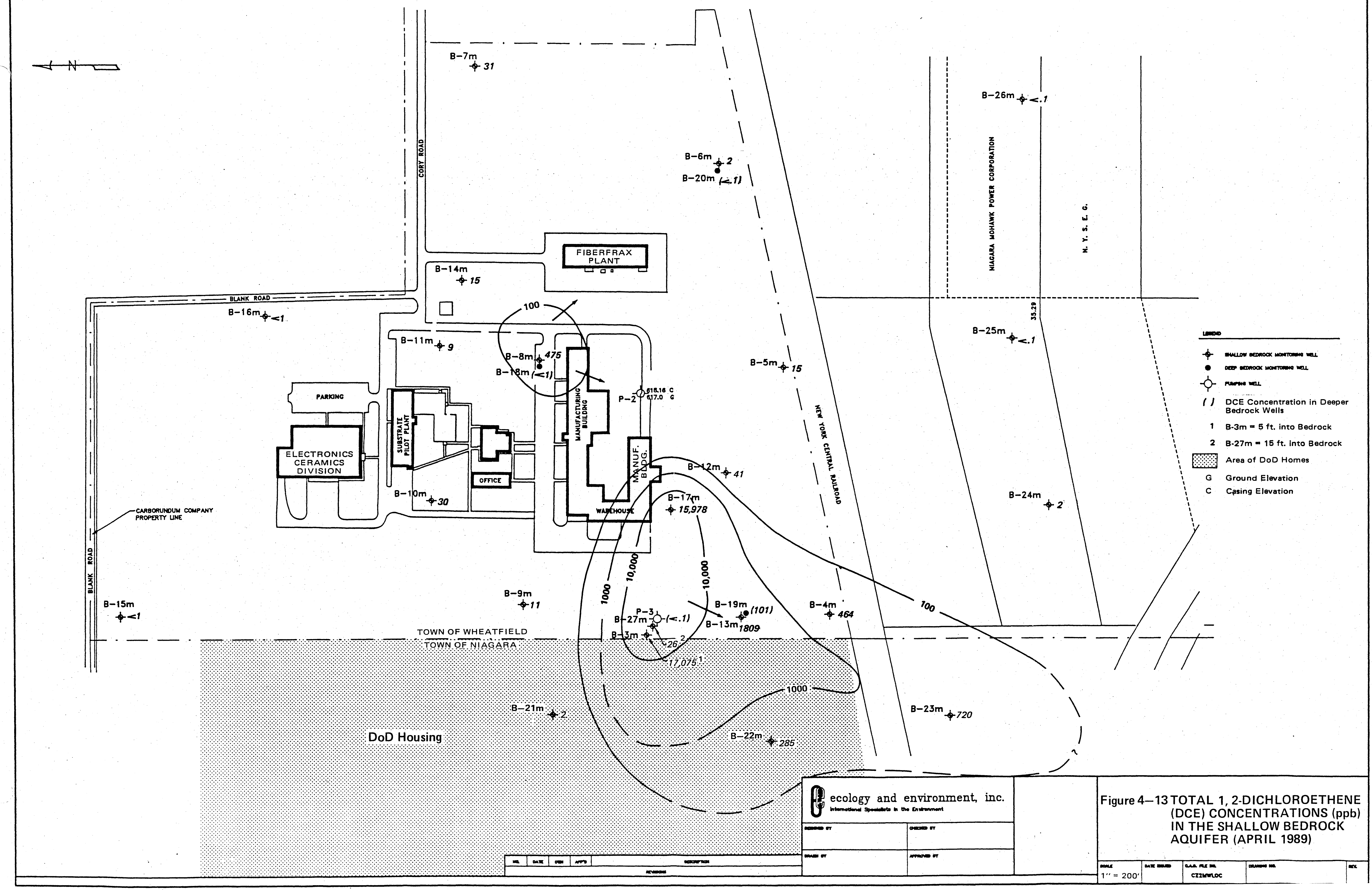

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Figure 4—13 TOTAL 1, 2-DICHLOROETHENE (DCE) CONCENTRATIONS (ppb) IN THE SHALLOW BEDROCK AQUIFER (APRIL 1989)

SCALE	DATE ISSUED	C.A.D. FILE NO.	DRAWING NO.	REV.
1'' = 200'		CZ2MWLOC		

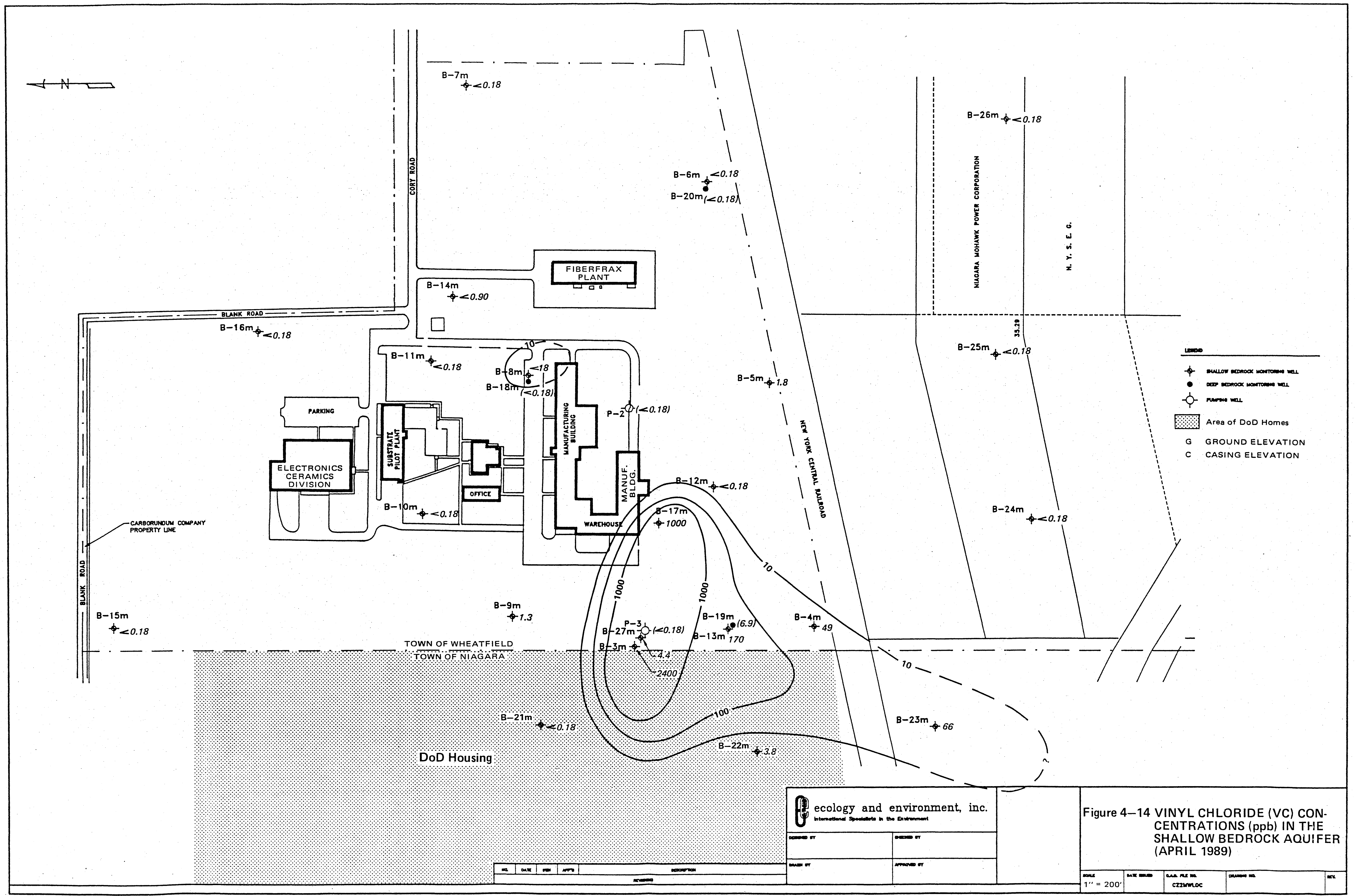

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Figure 4–14 VINYL CHLORIDE (VC) CONCENTRATIONS (ppb) IN THE SHALLOW BEDROCK AQUIFER (APRIL 1989)

SCALE	DATE ISSUED	C.A.D. FILE NO.	DRAWING NO.	REV.
1'' = 200'		CZ2MWLOC		

during the past six rounds of sampling (January 1989 through April 1990). The highest MC level detected in any of the downgradient wells was of concentration of 71 ppb in B-23M in January 1990. MC levels in all other downgradient wells (B-22M--B-26M and B-28M--B-31M) have been below or within 1 ppb of detection limits since January 1989.

Low levels of tetrachloroethene (0.3 and 9.9 ppb) have been found in two wells, B-9M and B-11M, upgradient of the primary suspected source areas. This is most likely not associated with any of the known sources since it is a parent product of TCE and was never used at the plant.

Migration of chlorinated organics in the groundwater plume off the Carborundum facility is restricted primarily to 1,2-DCE, VC, and TCE. The vast majority of chlorinated organics is migrating off the facility to the southwest. This conclusion is verified by the groundwater quality data from monitoring wells B-28M through B-31M which were installed during the Phase II RI field investigation. In April 1990, the furthest downgradient migration of chlorinated organics was detected in monitoring wells B-29M and B-30M. Levels of 1,2-DCE, VC, and TCE were 73 ppb, 2.6 ppb, 2.8 ppb, respectively in B-29M (see Plates 3, 4, and 5). The concentration of 1,2-DCE in B-30M was 42 ppb; VC and TCE were below detection limits in B-30M. The concentrations of the compounds detected from the April 1990 sampling are near or below drinking water standards in these wells. However, the concentrations of these compounds in B-29M and B-30M were higher and exceeded drinking water standards during the first period of sampling in January 1990. In B-29M, concentrations of chlorinated organics were 300 ppb for 1,2-DCE, 16 ppb for VC, and 12 ppb for TCE. In B-30M, concentrations of chlorinated organics were 110 ppb for 1,2-DCE, 12 ppb for VC, and 2 ppb for TCE. All chlorinated organics were below detection limits for B-28M for both sampling periods. It is important to note that levels of chlorinated organics were higher than usual throughout the site area during the January 1990 sampling round.

Data from the newly installed monitoring wells indicate that the groundwater plume is migrating off site principally to the southwest. The major controlling factor in the plume migration appears to be the high hydraulic gradient in this direction which is approximately five times greater than the gradient to the east and the southeast. Movement of chlorinated organics appears to be somewhat episodic, a characteristic which is most likely due to seasonal variations in the groundwater levels in the source area and consequent releases of chlorinated organics in a periodic or episodic fashion. While levels of chlorinated organics are high enough in B-29M and B-30M to warrant concern, they are an order-of-magnitude less than the nearest upgradient wells, B-29 and B-30M, which typically yield total concentrations of 1,2-DCE, VC, and TCE in the low ppm range. These data, in conjunction with the ancillary downgradient sampling data (residential, USGS well and quarry seep, which is summarized in Section 4.4.3), suggest that the plume attenuates prior to reaching any downgradient receptors.

4.4.3 Chlorinated Organics in Nearby Residential Wells, Sumps, the Downgradient USGS Well, and the Medina Sandstone Quarry

Residential wells were sampled three times during the course of this investigation. The first sampling was completed by the Niagara County Department of Health (NCDOH) in 1985 during which samples from 13 residential wells were collected. A low concentration of TCE (4.6 ppb) was found in one of the wells sampled in this study. However, this well was greater than 3/4 mile upgradient of the Carborundum plant and the TCE is not considered to be attributable to the facility. A second limited sampling event on nine residential wells was conducted in May and June of 1988. Only 5.1 ppb MC was detected in one upgradient well 1/2 mile northwest of the site; this is also not considered attributable to the facility. Samples were also collected by NCDOH during the second sampling event.

A third comprehensive residential sampling study was conducted in December 1988 in which 47 well samples, 41 sump samples, and one creek sample were taken from homes within a 3/4 mile radius of the Carborundum facility. VC was detected in five samples, one active well and four sumps, at concentrations ranging from 1.6 ppb to 39 ppb (see Appendix C). However, a trip blank, which was collected on the same day as two samples and analyzed on the same day as five samples, also contained VC at a level of 38 ppb. Thus, it was suspected that some type of interference, probably laboratory, resulted in false positives. Two of the five samples were also collected at a location that is hydrologically upgradient and were not considered to be related to the facility.

A limited resampling was performed on January 26, 1989, to verify that VC levels detected in December 1988 resulted from some type of interference. Selected for the analyses were the two highest level sump samples (32 and 39 ppb) and the one active well sample (2.3 ppb). The sump locations were identical to those taken previously where VC was found in the trip blank during the December 1988 sampling. Only the active well was collected on a different day than the trip blank containing VC. However, during the resampling event, levels of VC and all of the chlorinated organics were found to be below detectable limits. Based on the results of the second sampling event, it can be concluded with reasonable certainty that the VC detected during the first sampling event was from an external source or was the result of laboratory interferences and that is was not derived from the Carborundum facility.

Low levels of bromodichloromethane were found in several downgradient wells and low levels of chloroform were found in many of the downgradient wells. These cannot be derived from the facility area, since no bromodichloromethane was found beneath the Carborundum facility, and because chloroform was found at similar low concentrations upgradient. Tetrachloroethene was also found in one downgradient well at 4.5 ppb, but since this chemical has only been found six times in groundwater from the facility, all at concentrations less than 10 ppb, it was also not attributed to the facility. A minor concentration of 0.79 ppb of total 1,2-DCE was detected in one well due east of the Carborundum facility. This could conceivably be site-derived. However, the concentration is so low that it does not present a risk to human health or the environment.

The USGS study well 1.5 miles southwest and downgradient of the Carborundum facility on Smith Brothers Farm was also sampled in November 1988 at nine depth-specific intervals. Only low levels of chloroform (maximum concentration: 6.1 ppb) were found in three samples collected from this well from 80 to 110 feet below surface. Quarry seep sampling was performed in the Medina Sandstone Quarry which is located 0.5 mile west-southwest of the Carborundum facility. Ten samples were collected from the quarry. Nine out of the 10 samples contained low levels (0.96-7.2 ppb) of MC.

Both the quarry seep and the USGS well sampling yielded low levels of chloroform and MC which are both minor chlorinated organics found in groundwater in the facility area. However, these two chemicals at the quarry and the USGS well are not considered to be attributable to the facility for two reasons. First, the chlorinated organics that would be expected to be found at such downgradient locations are VC and 1,2-DCE. These are the last derivatives of TCE, the principal source chemical, and have been found as the primary chlorinated organics at the two most downgradient monitoring wells, B-29M and B-30M. Second, chloroform and MC are common laboratory solvents and have been noted, when present in other sampling events from the facility, to often be the result of laboratory interferences. Thus, it is suspected that the presence of chloroform and MC in both sampling events resulted from laboratory interferences. However, no laboratory rinsate blanks were provided during either sampling event to verify this conclusion.

Taken together these results indicate that the chlorinated organics found beneath the Carborundum facility have not reached water supply receptors in downgradient areas.

4.5 FATE AND TRANSPORT

This section describes the actual processes which cause chlorinated organics to migrate through the subsurface. Migration will be traced from source to receptor and rates of migration will be estimated from geologic, hydrologic, and chemical properties of the system. Observed patterns in the plume's migration over time will be presented to support the proposed transport mechanisms.

Several physicochemical processes are affecting the plumes as they migrate through the subsurface. These processes include volatilization, biodegradation, dilution, dispersion, retardation (or adsorption), dissolved flow with the groundwater, and gravity-driven migration, as well as hydrodynamic processes caused by seasonal fluctuations of infiltration and water levels.

4.5.1 Volatilization

Volatilization at the surface is of minor significance to this study because of the age of the sources. Although some volatilization probably occurred immediately after any surface releases, most of these incidents would have occurred prior to the process shutdown in 1983 when the carbon and graphite cloth cleaning operation was terminated. Therefore, direct evaporation of the original materials from the surface and near-surface soils has probably occurred long since and ceased to be a significant removal mechanism.

Volatilization is an important pathway where it occurs at the vadose zone/water table interface. Some of the chlorinated organics are so volatile (i.e., VC) that they can actually migrate along this interface by volatilizing from the groundwater and can potentially flow through the bedrock-overburden interface in a gas phase faster than the groundwater flows through the aquifer. Some of these volatilized organics can also then dissipate into the atmosphere from the vadose zone.

4.5.2 Physical Properties Affecting Migration

The migration pathway for a surface release of denser than water chlorinated solvent is vertical travel through the unsaturated zone to the water table. The migration rate through the unsaturated zone is dependent on the moisture content of the soil (as controlled by evaporation, transpiration, and precipitation), on the porosity and permeability of the soil, and on the density and viscosity of the compound. A precise, quantitative estimate of the rate of flow through this zone is quite difficult to acquire because of the inherent variability of the controlling parameters with depth in the unsaturated zone and because of the difficulty in quantifying, in particular, the moisture content of the soil.

The solvents used at this site will first move through the overburden soils as a DNAPL under the force of gravity until the adsorption onto soil grains and the capillary pressure between grains (as influenced by the moisture content of the soil) inhibit continued gravitational flow. The compound will then begin to dissolve into the groundwater. The residual concentrations adhering to the soil particles will be washed down into the water zone by infiltration and seasonal changes in the groundwater elevation. Precipitation and groundwater fluctuations, therefore, become the driving forces of flow through the overburden. Because the flat topography of the Carborundum facility causes surface runoff to be minimal, most of the 35 inches/year of annual precipitation must either infiltrate into the soil or evaporate. The fall rains and spring snowmelt mobilize residual chlorinated organics in the unsaturated zone, carrying them to the groundwater. These seasonal, higher than average volumes of water essentially move water and chlorinated organics vertically through the unsaturated zone in a pulse-like manner.

Once reaching the water table, dissolved compounds will flow vertically and horizontally with the groundwater at a rate dependent on the vertical and horizontal hydraulic conductivity of the matrix and on the compounds tendency to adsorb to the soil or aquifer matrix. High concentrations of the organics found in the groundwater at the Carborundum facility will tend to sink through the water column because they are heavier than water (e.g., TCE). However, the overburden sediments in this area are quite fine-grained. Recent studies (Schwille 1988) have shown that TCE will tend to pool on top of the water table of a fine-grained aquifer until it has enough thickness for its weight to push through the intergranular surface tension, which can only happen with spills or leaks of sufficient size. This phenomena causes source plumes of TCE to migrate to deeper zones within the saturated overburden also in a pulse-like fashion, similar to the pulse-like migration through the unsaturated zone.

4.5.3 Migration Through the Overburden and Adsorptive Effects

Adsorption (retardation) of the TCE will play a larger role in the migration of the detected chlorinated organics as they move through the overburden than when migrating through the bedrock aquifer because of the higher organic carbon content and surface area of the overburden materials. For example, the estimated retardation factors for TCE in a soil with 0.25% to 1.0% organic carbon content are 3.2 to 9.8, indicating TCE migrates at about 1/3 to 1/10 the rate that groundwater flows through the overburden. Similar ranges of estimated retardation factors for the other primary organics found in the groundwater (assuming the same range of organic carbon content) are:

Vinyl chloride (VC)	R = 1.9 - 5.0
1,2-dichloroethene (DCE)	R = 1.9 - 5.1
Trichloroethane (TCA)	R = 3.7 - 11.6
Dichloroethane (DCA)	R = 1.5 - 3.1
Carbon tetrachloride	R = 4.1 - 13.6
Methylene chloride	R = 1.2 - 1.6
Chloroform	R = 1.5 - 3.0

The direction of flow through the overburden is controlled by hydrodynamics. The geologic properties of the overburden soil indicate the transmissivity of this zone in either the horizontal or vertical directions is very slow. Silty clays of this sort have a hydraulic conductivity on the order of 10^{-5} to 1 gpd/ft^2 (10^{-9} to 10^{-4} cm/s) (Freeze and Cherry 1981). Johnston (1964) quotes an isolated measured value of the conductivity of the overburden in the silty clay interval to be 0.04 gpd/ft^2 (10^{-6} cm/s). These low conductivities, combined with low horizontal gradients, result in quite slow lateral flow velocities. Although vertical transmissivities through the overburden are also very low, the probability of a higher vertical gradient to exist between the overburden and the bedrock as compared to lateral gradients across the overburden (whose surface topography is flat) suggests migration occurs more readily vertically through the overburden than horizontally. This is supported by observations from borehole drilling and soil gas surveys implying that most of the overburden chlorinated organics have migrated to deeper soil depths and remained quite localized near the source areas. Overall, concentrations increase with depth reaching peak concentrations at either the 8- to 12-foot depth interval or at the bottom of the overburden, immediately above bedrock.

Water in the overburden does not represent a separate "aquifer" of concern beneath the facility because it does not have the capability to transmit significant quantities of water to receptors downgradient. The overburden acts as a saturated aquitard which stores water from precipitation and infiltrates or receives groundwater to and from the bedrock.

The vertical hydraulic gradient between the overburden and the bedrock has not been specifically determined but most likely is seasonably variable. Undoubtedly any gradient which exists changes seasonally because of the different hydraulic conductivities of these two intervals, and consequently the different rates in which they respond to the influx of water. It is anticipated that the vertical gradient will be downward based on the average water depth in the overburden (see Table 4-6) compared to the average water depth in the bedrock, causing groundwater to migrate vertically from overburden to bedrock. When the hydraulic head in the bedrock aquifer drops below the overburden-bedrock interface, a more pronounced downward gradient from overburden to bedrock may be developed. Water levels in the less permeable overburden will fall at a slower rate than water levels in the more transmissive bedrock. At other times of the year, such as spring and winter when the shallow bedrock head is very high, there may be no vertical gradient between the overburden and bedrock, or the gradient may be upward.

4.5.4 Migration Through the Bedrock

Once the chlorinated organics have migrated through the overburden to the top of the bedrock, they will move readily, in most cases, into the bedrock groundwater because the upper bedrock surface is usually quite weathered and fractured. It has been observed that concentrations tend to increase in most of the bedrock monitoring wells when water levels are high, and drop when water levels are low (see Figure 4-15) with the exception of B-12M, B-17M, B-3M and, to a lesser degree, B-13M. During high groundwater periods (winter and spring), the horizontal hydraulic gradient through the shallow bedrock aquifer is higher (see Figures 4-5 and 4-6) than during drier periods (Figure 4-7). In winter and spring the entire bedrock interval is saturated except in the very southwest corner of the site. This causes more of the overburden to be in contact with groundwater in the bedrock aquifer. This increased flow through the groundwater system probably increases mobilization of the chlorinated organics from the source areas toward the screened zones in the monitoring wells.

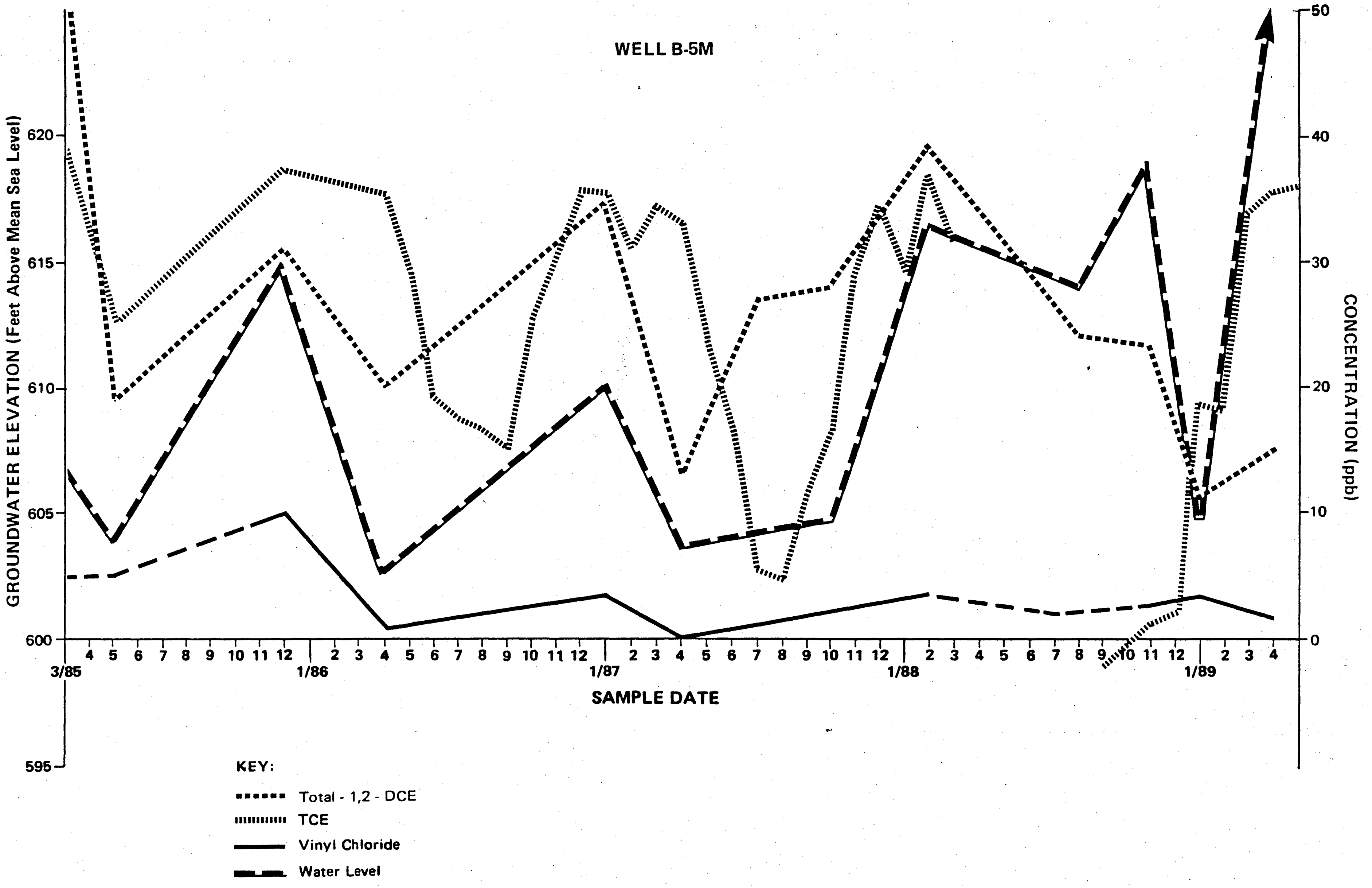


Figure 4—15 SEASONAL FLUCTUATIONS IN GROUNDWATER ELEVATION AND CHLORINATED ORGANIC CONCENTRATIONS

B-12M and B-17M are both installed into fairly unfractured rock within the top of bedrock, both having a Rock Quality Designation (RQD) (percent of intact core recovered per length of cored interval) of 100% for the first cored interval in the bedrock. B-3M and B-13M are also relatively unfractured at the top of bedrock, having RQDs of 94 to 95%. Chlorinated organics may not be able to migrate as readily into the shallow bedrock aquifer where the bedrock is less fractured nor migrate away from these areas once the groundwater contains chlorinated organics.

Shallow wells in the southwest corner of the study area in general are in poor hydraulic connection with the shallow bedrock aquifer which underlies the remainder of the facility. This can be seen by the difference in their seasonal groundwater fluctuations and in the resulting steep gradient created by the high water levels in the spring (see Figure 4-6), as well as by the pumping test results. The average seasonal groundwater fluctuation across most of the area is on the order of 10 to 12 feet, but the water level in wells to the southwest, beyond the hydraulic boundary, only fluctuates on the order of 2 to 4 feet seasonally. The same wells which have smaller seasonal fluctuations in groundwater elevation (B-13M, B-4M, and B-23M) also did not respond to pumping in either the pumping test conducted on P-2 or the test on P-3. The 4-foot seasonal fluctuations in groundwater elevations and the presumption of lower transmissivity in the wells southwest of the hydraulic boundary both agree with data from more regional studies of the Niagara Falls area (Johnston 1964). This variability in aquifer properties supports the interpretation that the shallow bedrock aquifer beneath much of the Carborundum facility lies within a localized more highly fractured or weathered zone.

As briefly discussed in Section 4.2.2, the change in hydraulic properties across this subsurface hydraulic boundary does not extend to depth. (The approximate location of this boundary is shown on the groundwater map, Figure 4-5). B-19M, which is located beyond this hydraulic boundary, exhibits much larger seasonal groundwater fluctuations (on the order of 15 feet), than the adjacent shallow bedrock well, B-13M. (B-19M is screened from 54 to 69 feet and B-13M is screened from 23 to 33 feet.) B-19M is in much better hydraulic connection with the shallow bedrock aquifer under the majority of the study area than is B-13M. B-19M also responded to pumping of P-3 whereas the other deep bedrock wells did not.

Chlorinated organic concentration patterns are further proof of the ease with which groundwater flows from the shallow bedrock zone under the main plant to the vicinity (and depth) of B-19M. B-19M exhibits significantly higher concentrations than the other two deep bedrock wells. A zone of vertical fracturing must exist between B-19M and the shallow bedrock, which provides a conduit for vertical flow through the 20-foot interval between these zones. Although the rates of flow may be slower in the shallow bedrock beyond the hydraulic boundary in the southwest, chlorinated organics are still able to migrate downgradient to these areas. Elevated levels of 1,2-DCE and VC, both TCE degradation products, have been found in the farthest downgradient well (B-29M) at maximum concentrations of 300 ppb and 16 ppb in January 1990.

4.5.5 Rate of Migration Through the Bedrock

It is very difficult to estimate the rate of chlorinated organic migration through the bedrock beneath the Carborundum facility. This is because the velocity of the plume is highly dependent on the interconnectedness of the fractures. The connections and frequency of the fractures controls the hydraulic conductivity (K) of the formation. The effective porosity (n_e) in turn controls the rate or velocity at which chlorinated organics move through the aquifer ($V = Ki/n_e$; where V = velocity, K = hydraulic conductivity, i = hydraulic gradient, and n_e = effective porosity).

The only available data to use in estimating effective porosity of the shallow bedrock beneath the Carborundum facility are core descriptions. Various studies of the shallow fractured Lockport Dolomite have modeled migration rates through the aquifer using a range of estimated porosities. The extensive aquifer evaluation at Hyde Park in Niagara Falls, New York, involved models where an effective porosity of 0.1 to 0.001 (Faust 1985) was assumed. A study conducted by Osborne and Sykes from the University of Waterloo on the same area assumes a porosity of 0.03 for the upper Lockport interval and 0.001 for the lower Lockport

(Osborne 1985). However, these values are literature-derived estimates which are not site specific.

The hydraulic properties of the shallow bedrock aquifer on site have been fairly well defined from the two long-term pumping tests. The average transmissivity in the west quadrant is approximately 29,850 gpd/ft which correlates to a hydraulic conductivity of 226 ft/day if the thickness of the aquifer is assumed to be 15 feet (15 feet is equal to the average thickness of the tested bedrock intervals in the wells which responded to pumping of P-3). The average transmissivity of the shallow bedrock aquifer in the central portion of the site is 23,900 gpd/ft (equivalent to K = 320 ft/d for a 10-foot-thick test interval). The gradient varies seasonally and locally across the site from 0.07 ft/ft across the hydraulic boundary in the spring to 0.003 ft/ft toward the east-southeast in the summer. Assuming a maximum effective porosity of 0.10, these data result in groundwater flow velocities of 13 to 224 ft/day. If the effective porosity is on the order of 0.01, the range of expected groundwater velocities is much faster, between 133 and 2,240 ft/day.

Chlorinated organics will tend to be both adsorbed to organic material in the aquifer matrix and to biodegrade. The organic material content of the bedrock is anticipated to be quite small, however, and retardation factors estimated to generally be less than 5 for the compounds found on the site (see ranges of retardation factors calculated for all the compounds listed in Section 4.5.3). A retardation factor of 5 indicates the chlorinated organic will migrate at 1/5 the velocity of the groundwater; a retardation factor of 1 implies the contaminant will flow at the same velocity as the groundwater. The minimum rate at which chlorinated organics could be expected to migrate away from the source areas is therefore 1/5 of Vmin (13 ft/d) or 2.6 ft/d (949 ft/yr). If the average gradient across the areas is estimated from the potentiometric surface maps to be 0.015, the effective porosity assumed to be 0.01, K taken to be 300 ft/d and R set to 5, the resulting velocity would be:

$$V_{\text{Contaminant}} = V/R = Ki/Rn = \frac{(300)(0.015)}{(5)(0.01)} = 90 \text{ ft/d} = 6 \text{ mi/yr}$$

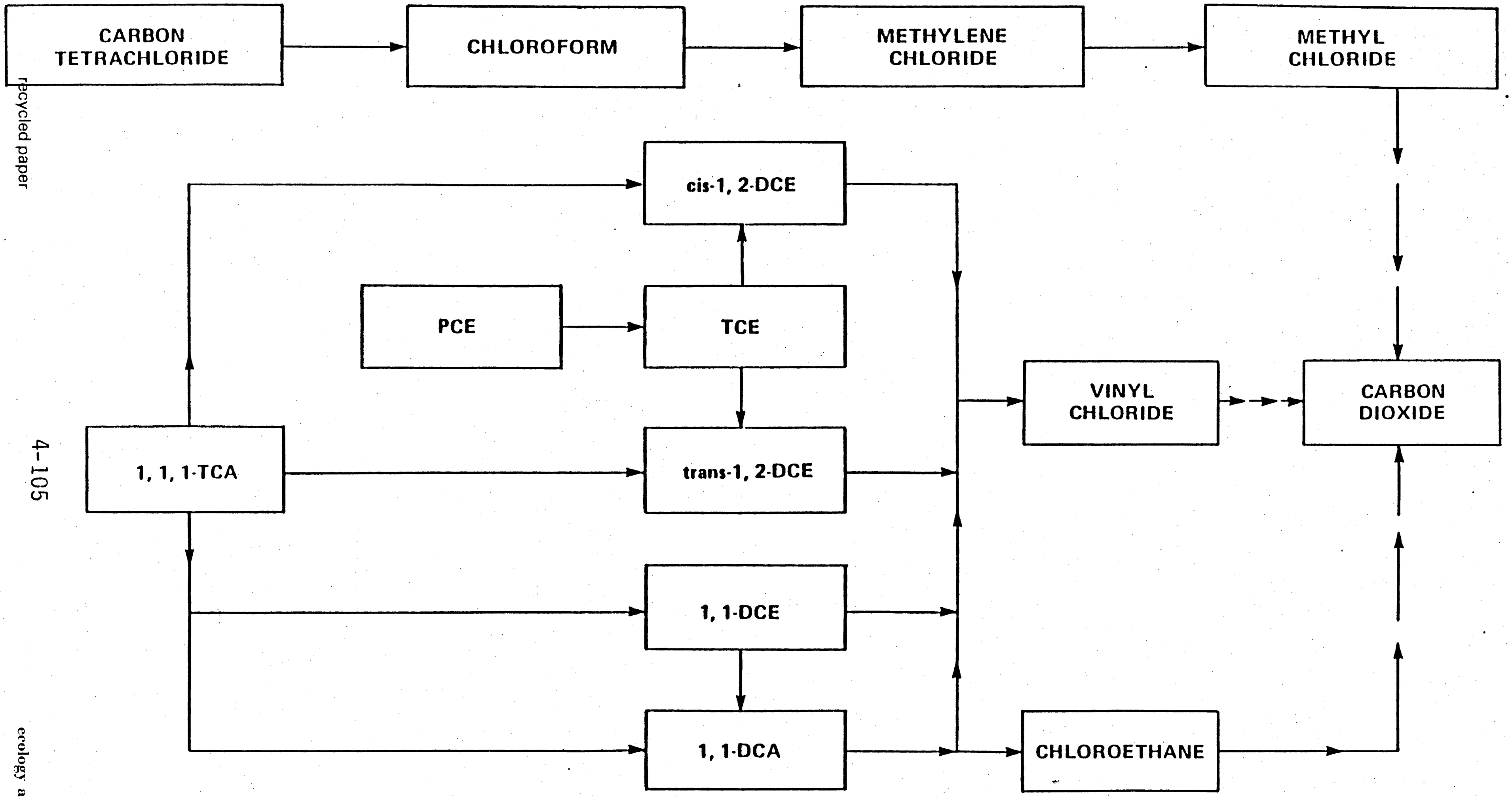
If the plume velocity is considered to be 6 miles per year, significant levels of chlorinated organics should reach the USGS well and the Niagara Stone Quarry within one year, and monitoring wells B-22M and B-23M within two weeks. Considering this scenario, the chlorinated organics found in monitoring wells B-29M and B-30M should be primarily TCE rather than its degradants VC and 1,2-DCE (insufficient time would exist for biological degradation in two weeks). Additionally, VC and 1,2-DCE would be expected to be present in the USGS well and the Niagara Stone Quarry. Consequently, the plume velocity is more than likely about 10 feet/day rather than the above-noted estimate of 90 ft/day (6 miles/year). This velocity provides a more reasonable time-frame for the source chlorinated organics, primarily TCE, to degrade as they migrate off of the facility. The cause of the breakdown of TCE is most likely biodegradation.

Quite high concentrations of DCE and VC, which are biodegradation products of TCE, have been found extensively in the site area, as have the degradation products of TCA and carbon tetrachloride. TCE has not migrated far downgradient because of biodegradation. The process of biodegradation for these compounds, formation of the daughter products, and decay rates and patterns derived empirically from the historical site-specific data are discussed in the following section.

4.5.6 Biodegradation

Over the past 5 to 10 years numerous reports have appeared in the literature indicating that, under reducing conditions, chlorinated one and two carbon alkanes and alkenes can undergo successive, biologically mediated, reductive dehalogenation in soil and groundwater (Bouwer, et al. 1981; Parsons, et al. 1984; Wilson and Wilson 1985; Smith and Dragun 1984; Vogel and McCarty 1985; Barrio-Lage, et al. 1986, and Barrio-Lage, et al. 1987). The studies report the results of laboratory microcosm studies; the phenomenon has also been observed and documented at a number of hazardous waste sites (Tsentas and Supkow 1985; Keely 1987).

The transformation pathways that have been identified by various investigators are shown in Figure 4-16. The steps involved in the final



SOURCE: Adapted from Smith and Dragun, 1984.

Figure 4—16 TRANSFORMATION PATHWAYS FOR VARIOUS CHLORINATED ORGANICS IN SOIL-GROUNDWATER SYSTEMS mineralization of the monochlorinated degradation products, MC, chloroethane, and VC, to carbon dioxide have not been elucidated in detail, however, there is radiotracer evidence that these final steps do occur (Vogel and McCarty 1985).

The Carborundum facility history indicates that the only chlorinated organics known to have been used at the plant were TCE, 1,1,1-TCA, carbon tetrachloride, and MC. All other chlorinated organic compounds found in the soil and groundwater at the facility, are assumed to be present as a result of the biodegradation of these compounds. Minor amounts of carbon tetrachloride, MC, 1,1,1-TCA, and PCE may have also been impurities in industrial grade TCE that was used by Carborundum.

TCE and its degradation products 1,2-DCE and VC are the predominant chlorinated organics that have been found in the soil and groundwater at the Carborundum facility. Concentrations of the first degradation product, 1,2-DCE, have been observed which are as high or higher than those of the parent compound, TCE. This indicates that biodegradation via the reductive dechlorination pathway is probably the primary removal mechanism for TCE at the facility.

The reductive dehalogenation process occurs only under anaerobic conditions and the chlorinated organics found at the facility are not known to undergo degradation under oxidizing (i.e., aerobic) conditions. Therefore, biodegradation of the chlorinated organics at the Carborundum facility would be expected to occur in the groundwater, which can be anaerobic, but not in the unsaturated zone which is partially occupied by air.

There is relatively little information available on the rates at which these transformations occur; however, the kinetics of two of the steps relevant to the Carborundum facility have been investigated and half-lives estimated. Barrio-Lage, et al. (1987) reported that in two experiments the half-life for the conversion of TCE to DCE averaged 42 days and Barrio-Lage, et al. (1986) reported that the half-life for the conversion of cis- or trans-1,2-DCE to VC averaged about 140 days in two experiments per compound. The latter study also showed that the reaction rate depends on the type and organic content of the soil. Other site-specific factors such as the availability of required nutrients, the presence of an adequate microbial population capable of degrading these compounds, and a contaminant concentration adequate to support the biomass would also be expected to affect the occurrence and rate of these transformations. The observation of large quantities of the TCE degradation products indicates that conditions at the facility are favorable for the reductive dechlorination process.

The changes in the contaminant concentrations observed in most of the Carborundum facility monitoring wells over time do not exhibit the logarithmic decline that is characteristic of a first-order removal process such as biodegradation. This is because there are other factors that influence these concentration patterns. The most important additional factors are probably the patterns of chlorinated organic inputs to the groundwater (which appear to be episodic but could also be continuous, or variable), and seasonal fluctuations in groundwater levels and rates of movement. There are two wells, B-3M and B-4M, which do show a logarithmic decay pattern for one or two compounds. The pump test data indicated that these wells were not well connected hydrologically to the groundwater in the remainder of the site. B-4M is on the downgradient side of the hydraulic boundary, and B-3M is drilled into only the upper 5 feet of bedrock and does not respond to pumping well P-3 as readily as B-27M which was drilled 15 feet into bedrock. Therefore, these wells may not have received any new chlorinated organic inputs for the past several years.

In B-3M, the annual average TCE concentration declined logarithmically from 1985 through 1988 with a half-life of 226 days while in B-4M TCE decreased from 1986 through 1988 with a half-life of 485 days and 1,2-DCE decreased from 1985 through 1988 with a half-life of 613 days. In each case the correlation coefficient for the log-linear regression was greater than 0.997. These disappearance rates are five to 10 times slower than those observed in the laboratory microcosm studies cited earlier; however, the microcosms were maintained at 25°C while the Carborundum facility groundwater probably had an average temperature of 11°C, which would slow the reactions by at least a factor of 2. In addition, the degradation process at the facility took place in a fractured bedrock aquifer which would normally have a lower organic content and lower biological activity than some of the soils used in the microcosm studies. Taking these factors into consideration, the apparent degradation rates seen at the Carborundum facility are in reasonable agreement with the literature data.

Knowledge of the biodegradation pathway and the relative rates of some of the transformation steps may provide a separate line of evidence, in addition to the hydrogeological information, about migration patterns and the general location of possible source areas. As TCE begins to degrade, 1,2-DCE is formed, and, since its rate of formation is faster than its rate of degradation, 1,2-DCE begins to accumulate. As degradation proceeds the TCE concentration will fall and the 1,2-DCE concentration will increase until the 1,2-DCE concentration exceeds the TCE concentration and 1,2-DCE becomes predominant. Also, as the 1,2-DCE concentration builds, VC begins to be formed. There is no information on the relative rates of formation and degradation of VC; however, in most cases the VC concentration did not seem to exceed about 10% of the 1,2-DCE concentration. Therefore, it may be that VC degrades and/or volatilizes faster than it is formed from 1,2-DCE.

Another factor that contributes to the concentration pattern seen in a particular well is the relative mobility of the compounds. The retardation factor for TCE is about twice that for 1,2-DCE and VC; thus, 1,2-DCE and VC should move through the aquifer twice as fast as TCE.

Assuming that TCE is the primary chlorinated organic and applying the knowledge of the degradation pathway and mobility properties of the compounds, the pattern corresponding to several arbitrary "stages" of the process can be described. In stage 1, when the TCE has only recently entered the groundwater and become exposed to the anaerobic conditions necessary for the biologically mediated reductive dehalogenation to occur, TCE would be the major compound present, with small amounts of 1,2-DCE and little or no VC. In stage 2, 1,2-DCE will have accumulated to the point that roughly equal concentrations of TCE and 1,2-DCE are present and VC may have begun to appear. In stage 3, most of the TCE will have been converted to 1,2-DCE, and VC will have reached its apparent equilibrium concentration of about 10% of the 1,2-DCE concentration. The average relative abundance of TCE, 1,2-DCE, and VC in the monitoring wells in which significant quantities of these compounds were found and for which at least two years of data have been compiled are given in Table 4-9. Also included in Table 4-9 is the "stage" to

Table 4-9

AVERAGE RELATIVE ABUNDANCE OF TCE AND ITS BIODEGRADATION PRODUCTS 1,2-DCE AND VC IN FACILITY MONITORING WELLS

	Average Weight Fractions*			
Well	TCE	1,2-DCE	VC	Degradative "Stage"
B-3M	0.066	0.84	0.091	3
B-4M	0.15	0.82	0.03	3
B-5M	0.19	0.75	0.07	3
B-6M	0.66	0.27	0.07	2
B-7M	0.59	0.41	--	2
B-8M	0.93	0.04	0.02	1
B-10M	0.55	0.45	--	2
B-11M	0.89	0.11	--	1
B-12M	0.55	0.43	0.02	2
B-13M	0.06	0.88	0.06	3
P-2	0.82	0.17	0.01	1

[AD]CZ4140:D2467, #2344, PM=36

*August 1984 through January 1989.

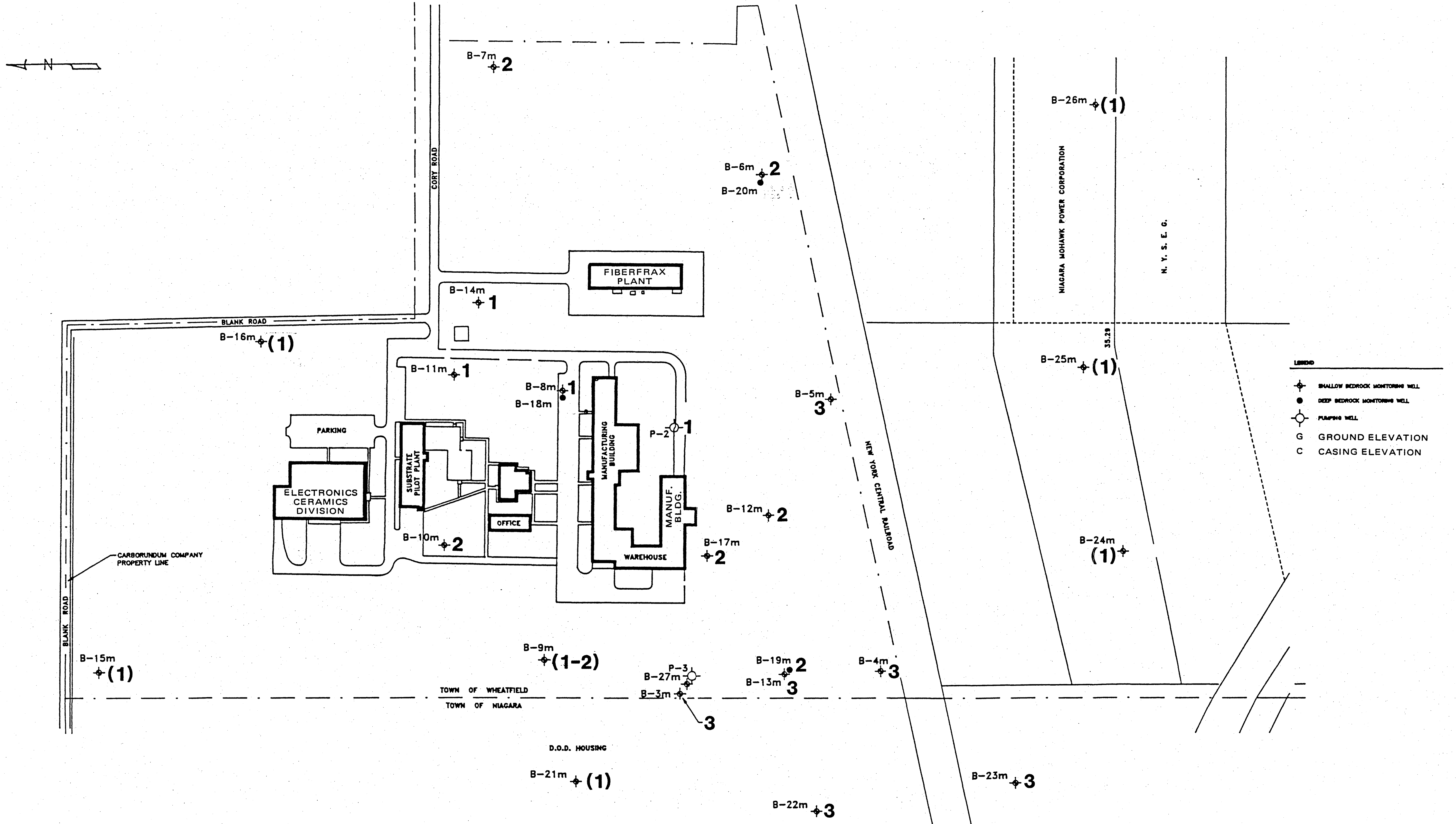
which the well's profile corresponds. Figure 4-17 presents a map of the site showing the stages to which the various wells' profiles correspond. For wells not included in Table 4-8, the stage was determined by inspection of the limited data available.

The main stage 1 wells are P-2, B-8M, B-11M, and B-14M which are all located close to known or suspected source areas. Two upgradient wells, B-15M and B-16M, along the northern perimeter of the facility, and three wells, B-24M, B-25M, and B-26M, off site south of the facility, each had one or two occurrences of very low TCE concentrations (less than 10 ppb) without either 1,2-DCE or VC. These wells would thus technically fit the description of stage 1 wells but the significance of that for these wells is not evident.

The stage 2 wells include wells B-6M, B-7M, B-10M, B-12M, B-17M, and B-19M, most of which are somewhat removed from the known or suspected source areas, generally in a downgradient direction. B-17M is a notable exception. It is located right at a suspected source area and an area in which high soil gas readings were obtained, yet it exhibited a profile in the stage 2 category. It appears that the chlorinated organics found in this well either first entered the groundwater some distance from the well location, or that overlying chlorinated organics in the B-17M area have not migrated away from the area, but are in all likelihood degrading in-place in the saturated overburden before entry into the bedrock aquifer. This later interpretation is supported by the observed tight top of bedrock described when the B-17M well was cored.

The stage 2 pattern seen in well B-19M is also interesting because it contrasts with the stage 3 pattern seen in well B-13M. These wells are located side by side with B-13M screened in the top of rock while B-19M is screened 20 feet deeper. The pumping test indicated that these two wells were not well connected hydrologically and their concentration patterns seem to confirm this. Other stage 3 wells are B-3M, B-4M, B-5M, B-22M, B-23M, B-29M, and B-30M, which are all south to southwest of the suspected source areas and generally somewhat farther away than the stage 2 wells in those directions.

In general, the chlorinated organic profile information indicates that the most recent sources of TCE appear to first reach the groundwater in the vicinity of wells P-2, B-8M, B-11M, and B-14M, which is in



NOTE:
NUMBERS IN PARENTHESES INDICATE WELLS WHICH SHOWED THE STAGE 1 PATTERN AT VERY LOW CONTAMINANT CONCENTRATIONS

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Figure 4–17 CARBORUNDUM FACILITY MAP SHOWING THE STAGES OF THE TCE BIODEGRATION PROCESS OBSERVED IN THE FACILITY MONITORING WELLS

SCALE 1" = 200'
DATE ISSUED
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the general location of many of the known or suspected sources. The profiles appear to get progressively older for wells farther removed from the suspected sources area, particularly in a southwesterly direction. However, the notable exception to this trend is well B-17M, which is screened immediately beneath a suspected source area but is ranked as stage 2. Most likely the trend observed at B-17M reflects higher degradation rates in the overburden than the other source area where direct monitoring is available as in the area of B-8M. Chlorinated organics detected in the B-8M area are much less degraded because they originate from suspected leaking septic system tanks that are subject to much lower degradation rates than have been observed in the B-13M to B-17M area.

4.5.7 Chlorinated Organics Loading

Rates of off-site loading were estimated for the Carborundum site. Estimates were completed for surface water and groundwater. Surface water runoff at the facility is relatively low because the topography of the site area is fairly flat. What surface water that does exist is directed via drainage ditches into the POTW. The other significant discharge into the POTW are noncontact cooling waters from the manufacturing building. These waters are currently discharged under an agreement with the Niagara County Sewer District 1.

In the past, water from P-2 has been used in this process and then discharged to the POTW. Because of the difficulty of determining surface water flow and the sparse surface contamination which exists at the site, an estimate of surface water loading was completed by using the total monthly discharge to the POTW and the concentration of chlorinated organics in the sewer as determined by monthly sampling. Thus, the estimate is considered to be high. Surface water loading in pounds per day (lbs/day) was calculated from the following equation:

$$\text{Loading}_{\text{SW}} = \frac{(\text{gallons/month})(8.345\ \text{lbs/gallon})(\text{monthly concentration})}{\text{number of days per month}}$$

The period considered in this calculation was from April through December 1989 because the wastewaters were analyzed for the entire suite of chlorinated organics using EPA Method 8010. Only one compound, TCE, was analyzed previous to this period. Results of these estimates are present in Table 4-10. The average daily loading to the POTW during this period was 0.04 pound. The maximum and minimum daily loading were 0.08 pound in April and 0.002 pounds in September. TCE, TCA, and 1,2-DCE were the most common compounds detected in the monthly sampling. For comparison, the highest and lowest daily loadings to the POTW for TCE only in 1988 were 0.22 lb/day in March and 0.002 lb/day in December.

The following equation was used to calculate daily loading off site from the groundwater plume:

$$\Sigma \text{ Loading}_{GW} = (K,I,A)(8.345 \text{ lbs/gallon})(C)$$

where:

K = Average site hydraulic conductivity of 2,190 gpd/ft^2;
I = Hydraulic gradient considered;
A = Cross-sectional area;
C = Concentration ration in ppb; and
Σ = Sum of loading from all wells considered.

The cross-section area A was determined by the product of equal linear distances between wells multiplied by an average shallow aquifer thickness of 15 feet.

Loading estimates were determined for the groundwater plume moving toward the southwest and south for two sampling periods, August 1987 and April 1989. Concentrations in groundwater from wells B-9M, B-3M, B-13M, B-4M, and B-5M, which are located near the facility boundary, were used to determine these estimates. These sampling periods were selected because there was fair variability in chlorinated organic concentrations and in the hydraulic gradient relative to other sampling periods. The hydraulic gradient in this area for April 1989 was 0.0314 ft/ft and for August 1987 was 0.0156 ft/ft. The resulting range of loading estimates to the southwest were 23.0 lbs/day for August 1987 and 69.41 lbs/day for April 1989. These estimates represent a worst case scenario. There is a three-fold difference in the two loading estimates. This extreme

Table 4-10

MONTHLY LOADING TO THE POTW FROM APRIL - DECEMBER 1989

Month/ 1989	Total Discharge (in million gallons)	Concentration Total Chlorinated Organics (ppb)	Detected Compounds	Date of Sampling	Monthly Total Loading (lbs)	Daily Average (lbs)
April	1.2	230	TCE	4/11/89	2.30	0.08
May	1.52	164	TCE	5/22/89	2.08	0.07
June	1.4	162	TCE	6/14/89	1.89	0.06
July	1.9	47.2	TCA, TCE, bromodichloromethane	7/13/89	0.75	0.02
August	1.9	45.0	1,2-DCE, TCA, TCE, VC, dibromochloromethane	8/16/89	0.71	0.02
September	1.2	5.0	TCE, dibromochloromethane	9/20/89	0.05	0.002
October	1.0	34.1	1,2-DCE, TCA, TCE, VC	10/20/89	0.29	0.01
November	2.2	80.2	1,2-DCE, TCA, TCE, VC, 1,4-dichlorobenzene	11/29/89	1.47	0.05
December	3.5	31.4	1,2-DCE, TCE	12/03/89	0.92	0.03
Average					1.16	0.04

[AD]CZ4140:D2467, #3400, PM = 22

variability results from fluctuations of chlorinated organics levels in the groundwater plume and the effect of decreasing hydraulic gradient from the spring to the summer.

The loading estimates are also high. Two factors, an anomalously high hydraulic conductivity for the site area and a very high loading estimate from well B-3M, are responsible for the high estimates. Well B-3M accounted for 92% of the estimate in April 1989 and 67% of the estimate in August 1987. In both cases, an area of 3,900 ft^2 (260 feet by 15 feet) was used in the calculation. This area is well within the distance between B-3M and B-27M. Levels of chlorinated organics in B-27M are much lower than B-3M. In fact, for April 1989 the loading from well B-27M was 0.0955 lb/day whereas the loading from B-3M was 60.64 lbs/day. By averaging the B-27M value with the B-3M value, the resulting estimates would decrease to 15.25 lbs/day for August 1987 and 39.13 pounds/day for April 1989.

The hydraulic conductivity for the upper Lockport on site is several orders of magnitude higher than the average value for the Lockport Dolomite. If average hydraulic conductivity values for the upper Lockport are applied, then both loading estimates decrease to less than 1 lb/day. Pump test data have suggested that hydraulic conductivity decrease off site. Thus, it is possible that a lower hydraulic conductivity off site would decrease these estimates.

Another means of determining the accuracy of the groundwater loading estimate is to assess the maximum amount of chlorinated organics present in the overburden source areas. By using a worst case estimate of 4 acres of contaminated soil with concentrations of 100 ppm of TCE and an overburden total porosity of 40%, the maximum TCE that could have been disposed in these areas is 12,700 pounds. Assuming the groundwater plume has existed for 10 years and that all the available TCE has leached into the plume, a source of only 3.5 lbs/day would be available. A more likely case of 2 acres of contaminated soil with concentrations of 50 ppm and a porosity of 40% would provide 0.3 lb/day over 10 years. Even the more likely case estimate is high because the source areas are still highly contaminated and the plume has probably existed for 15 to 20 years (based on the history of known handling practices).

The loading estimates based on calculations from groundwater data are not only variable but also appear to be higher than is realistically possible. Even the worst case estimates of loading from the source areas provide much lower (on the order of 6-fold) levels of chlorinated organics to the aquifer than would be needed to meet the minimal estimates for groundwater loading at the site boundary. The cause of the high groundwater estimate is the high hydraulic conductivity determined for the site area. As has been indicated from P-2 and P-3 pump test data, these high values of hydraulic conductivity most likely decrease off site. The actual loading to the off-site groundwater is ultimately controlled by levels of chlorinated organics which can be leached out of overburden source areas. As estimated previously, this level is probably less than 1 lb/day.

5. RISK ASSESSMENT

5.1 COMPOUNDS OF CONCERN

Chlorinated organics have been found in the subsurface soil, soil gas, and groundwater at and in the vicinity of the Carborundum facility, and in shallow sediment from the inactive SPDES outfall ditch leading to Cayuga Creek. Surface soils other than the inactive SPDES outfall sediments have not been analyzed for the presence of compounds of concern; however, the soil gas concentrations of these compounds have been measured and the risk that they pose to both workers and nearby residents is assessed.

The principal chlorinated organics found at the facility were 1- and 2-carbon compounds. TCE and its degradation products 1,1- and 1,2-DCE and VC were the most abundant compounds, followed by TCA and its degradation product 1,1-DCA. Lesser quantities of the chlorinated 1-carbon compounds, carbon tetrachloride, chloroform, and MC were also present. This group of compounds has been known to be present at the facility since 1983 and has been under investigation since that time. Consequently, the degree and extent of the presence of these compounds in the environment at the facility have been fairly well characterized.

On several occasions groundwater samples have been analyzed for substances other than the chlorinated organics. Metal concentrations were examined in the production wells at the facility in August 1984, in samples from the monitoring wells in existence in April 1986, and in a sample from well B-17M analyzed by NYSDEC in April 1989. Federal and state water quality standards for iron and lead were exceeded in the 1984 samples and the iron standards were exceeded in most of the 1986 samples and in the 1989 sample. The standards for iron are secondary standards based on aesthetic considerations (taste and odor) rather than potential adverse health effects. Groundwater obtained from the Lockport Dolomite, which is the uppermost bedrock formation underlying the site, has historically been of poor chemical quality because of its naturally high mineral content. The iron concentrations in 12 water samples from the Lockport Dolomite reported in a review of groundwater in Niagara County (Johnston 1964) ranged from 0.05 to 167 mg/L and had a geometric mean of 0.27 mg/L, which is just below the federal and state standards of 0.3 mg/L. The iron concentrations found at the Carborundum site are within those typical of the Lockport and no known sources of iron releases from the facility have been documented. Therefore, the iron concentrations found in the groundwater at the Carborundum facility are presumed to be of natural origin. Lead concentrations found on site are also typical of those found in groundwater in the Lockport Dolomite. Naturally occurring concentrations of lead from groundwater within the Lockport, which results from dissolution of a lead-bearing mineral galena, ranged from 0.3 - 0.8 ppm (Forquehar 1987). The concentration of lead detected in three wells at the facility, B-3M, B-17M, and P-2, ranged from 0.010 ppm in B-17M to 0.8 ppm in P-2M. Thus, lead concentrations found in groundwater at the Carborundum facility are also presumed to be of natural origin.

Several compounds in addition to the chlorinated organics were found in the sample from well B-17M analyzed by NYSDEC in 1989. These included phenol, 2- and 4-methylphenol, and benzoic acid. The total concentration of the three phenolic compounds, phenol and 2- and 4-methylphenol, was 0.075 mg/L, which exceeds the New York State standard for total phenolics class GA groundwaters of 0.001 mg/L. The state standard is based on aesthetic considerations (control of odor and taste). The acceptable drinking water concentration based on the EPA reference dose (RfD) for phenol (0.06 mg/kg/day; IRIS 1989), assuming that only 20% of an individual's daily intake of phenol is derived from drinking water, would be 4.2 mg/L. Benzoic acid was found at a concentration of 0.13 mg/L. There is no federal or state standard for benzoic acid in drinking water or groundwater. Benzoic acid is on the Food and Drug Administration's Generally Regarded As Safe list (21 CFR 184.1021) and is used in many food products as a preservative. The acceptable drinking water concentration based on the EPA RfD (4.0

mg/kg/day) and, again assuming that only 20% of an individual's daily benzoic acid intake came from drinking water, would be 28 mg/L.

Based on the foregoing discussion it appears that the compounds found at the Carborundum facility, other than the chlorinated organics, are either naturally occurring (iron and lead) or are present at concentrations well below those that could pose a potential threat of adverse health effects. Therefore, the chlorinated organics that have been under investigation at the facility since 1984 have been selected as the compounds of concern.

5.2 PATHWAYS OF EXPOSURE

There are four pathways of exposure to chlorinated organics at the Carborundum facility that may be of potential concern. These are:

- Exposure of facility workers to volatilized chlorinated organics emanating from subsurface soils and groundwater at the facility;
- Exposure of facility workers and the general public to chlorinated organics in shallow sediments in the inactive SPDES discharge ditch by inhalation of vapors and ingestion of small quantities of these sediments via direct dermal contact and hand-to-mouth transport;
- Exposure of residents living in the DoD housing area adjacent to the Carborundum facility to volatilized chlorinated organics emanating from groundwater passing beneath some of the residences, and from volatilization of chlorinated organics from the facility; and
- Exposure to chlorinated organics in the groundwater through use of the groundwater for residential water supply purposes.

A fifth potential exposure pathway, involving ingestion of chlorinated organics through consumption of vegetables or meat grown or raised near the Carborundum facility, was not considered for the following reasons. Chlorinated organics would not be expected to accumulate or concentrate in agricultural products or livestock to any significant degree. No specific information on this point was located in the available literature, however, the expectation of no significant accumulation or bioconcentration is supported by the physical chemical properties of these materials.

As a group, these compounds exhibit low organic carbon and octanol/water partition coefficients indicating that there is only a minor propensity for them to partition into vegetable matter. These compounds also exhibit high volatility which indicates that any quantity of these compounds that is taken up by vegetable matter would have a marked tendency to evaporate from the plant matter rather than accumulate in it. Livestock would presumably be exposed to the chlorinated organics by consuming feed materials grown near the Carborundum facility. Since the vegetation is unlikely to accumulate chlorinated organics, livestock would not be expected to experience any appreciable exposure and thus would have no opportunity to accumulate these compounds in their tissues.

These expectations for agricultural products and livestock are also supported by the low bioconcentration factors reported (EPA 1986a) for these compounds in fish, which range from 1.17 for VC to 10.6 for TCE. When these compounds are present in surface waters, fish living in those waters would be intimately and continuously exposed to them. The low bioconcentration factors observed for fish are therefore strong evidence that accumulation of these compounds in animal tissues under much more moderate exposure conditions would be quite unlikely. Since, for the reasons discussed, agricultural products and livestock are not expected to contain significant concentrations of chlorinated organics, human exposure through consumption of these materials has not been considered further in this risk assessment.

5.2.1 Exposure of Facility Workers to Chlorinated Organics Vapors Emanating From the Ground

Chlorinated organics have been found in the groundwater, in subsurface soils, and in the soil gas under much of the facility. Since the chlorinated organics are volatile, they have the potential to evaporate from the groundwater and subsurface soils, migrate through the soil gas in the unsaturated zone, and emerge from the ground to mix with outdoor air or diffuse through foundations and mix with indoor air. In either case individuals working at the facility could be exposed to the chlorinated organics by inhaling the vapors emanating from the ground. Since the chlorinated organics emanating from the ground come from the gas phase within the soil, soil-gas concentrations measured at the facility will be used to evaluate this potential exposure pathway.

5.2.2 Exposure of Facility Workers and the General Public to Chlorinated Organics in Shallow Sediments in the Inactive SPDES Outfall Ditch

Chlorinated organics were found in shallow sediments (average depth: 6 inches) from four sampling locations on the Carborundum facility and four downgradient locations off site. Individuals working at the facility could inhale the vapors, as discussed above, and could also ingest small amounts of the soil containing the chlorinated organics through direct dermal contact and subsequent hand-to-mouth transport. The sediment concentrations were used to evaluate the potential exposure and risks to facility workers and the general public.

5.2.3 Exposure of Residents Living in the DoD Housing Area to Chlorinated Organic Vapors

Chlorinated organics have been found in groundwater samples from monitoring well B-22M which was installed in the southeast corner of the DoD housing area in November 1988. The groundwater is not used for residential supply purposes in this area; however, the chlorinated organics could potentially volatilize from the groundwater, diffuse through the unsaturated zone, and emerge from the ground in the residential area either inside or outside of dwellings and thereby become available for inhalation by the residents. Chlorinated organics emanating from the ground in areas of high soil-gas concentrations on the Carborundum facility could also be carried by the wind into the DoD housing area and will be considered in evaluating this exposure pathway. Soil-gas data will be used to evaluate this pathway.

5.2.4 Exposure to Chlorinated Organics in the Groundwater Through Use of the Groundwater for Residential Supply Purposes

At the present time this is believed to be a hypothetical or potential exposure pathway only. Based on the December 1988 well sampling program, all of the residences within a 3/4-mile radius of the Carborundum facility are served by a public water supply system. However, at least five residences within a 3/4-mile radius of the facility do use groundwater for general residential supply purposes, and additional residences use it for non-potable purposes such as washing cars and watering lawns and gardens. Efforts have been made to identify and sample all of the wells and basement sumps within a 3/4-mile radius of the facility. No significant levels of chlorinated organics attributable to the facility have been found in any of these samples.

Nevertheless, for several reasons it is appropriate to consider the risks to human health that could arise if groundwater containing chlorinated organics from the facility was used for general residential supply purposes. First, the groundwater in the vicinity of the Carborundum facility is categorized by New York State as class GA water, which is groundwater for which the best usage is as a potable water supply. As discussed in Section 5.1, the groundwater in this area has a naturally high mineral content and is very hard. It often exceeds New York State class GA water standards for sulfate, iron, lead, and manganese concentrations and occasionally has a sulfide odor. These properties make the groundwater undesirable as a source of potable water at many locations in the vicinity of the Carborundum facility and, in general, in Niagara County. However, the groundwater has historically served as a potable water source (in 1964 Johnston estimated that 36,000 people in Niagara County relied on the groundwater as their source of potable water) and continues to be used as such by at least five residences within a 3/4-mile radius surrounding the Carborundum facility (see Appendix C, Table C-6). Additional residences have active wells that are presently used only for non-potable household purposes (see Appendix C, Table C-6) but which might be used as backup potable water sources if their public supply service were interrupted.

No significant levels of chlorinated organics believed to have originated at the Carborundum facility have been found in any active wells to date. The closest active wells potentially downgradient from the facility are located 0.3 to 0.4 mile south or southeast of the facility. Based on the observed decreases in chlorinated organic concentrations with increasing distances from the Carborundum facility, it appears that groundwater concentrations of these compounds are unlikely to remain above MCLs more than about 2,000 feet downgradient from the suspected source areas in those directions. This is despite the high estimated groundwater velocity and the fact that the primary compound believed to have given rise to the presence of chlorinated organics in the soil and groundwater (TCE) was used at the facility beginning in about 1963. The sequential biodegradation and eventual mineralization (conversion to carbon dioxide and chloride) of the chlorinated organics used at the facility as described in Section 4.5.5 seems to be the most likely explanation for the limited extent of the chlorinated organic migration observed.

While there are not any active wells immediately adjacent to the Carborundum facility at this time, it is always possible that the owner of an adjoining property could decide to install a well just outside the Carborundum property and begin using it as a source of potable water. For this reason it is the stated policy under the National Contingency Plan that, when potential remedial measures are being evaluated for effectiveness in meeting applicable or relevant and appropriate requirements (ARARs), all environmental media (air, water, and soil) at the property line and at all points beyond the property line must be taken into consideration, even if at the time there are no potential receptors for some distance beyond the property line. This policy and the possibility of the future usage of the groundwater close to the Carborundum facility were taken into consideration in deciding how and where to evaluate the potential health risks that could be associated with using the groundwater at or near the facility as a general residential water supply source.

5.3 RISK ESTIMATION METHODS

The risk estimation procedures utilized combine information on environmental media, chlorinated organic concentrations found in environmental media, estimates of receptor exposure by relevant pathways, and toxicological information in order to obtain an estimate of the risks posed by the presence of chlorinated organics at a site to human health. This section describes how toxicological information is incorporated into the risk estimation process. Subsequent sections and appendices will describe how exposure estimates for pathways relevant to the Carborundum facility have been obtained.

5.3.1 General Practices and Procedures

For the purpose of this risk assessment, the compounds of concern were divided into two groups, potential carcinogens and noncarcinogens. The risks posed by these two types of compounds are assessed differently because noncarcinogens generally exhibit a threshold dose below which no adverse effects occur, while no such threshold is believed to exist for carcinogens.

Risks associated with noncarcinogenic effects (e.g., organ damage, immunological effects, birth defects, skin irritation, etc.) are usually assessed by comparing the estimated average exposure to the acceptable daily dose, now called the "reference dose" (RfD) by EPA. The RfD is selected by identifying the lowest reliable no observed or lowest observed effect level (NOEL or LOEL) in the scientific literature, then applying a suitable safety factor (usually ranging from 10 to 1,000) to allow for differences between the study conditions and the human exposure situation to which the acceptable daily dose is to be applied. NOELs and LOELs are usually based on laboratory experiments on animals in which relatively high doses are used. Consequently, uncertainty or safety factors are required when deriving RfDs to compensate for data limitations in the experiments and the lack of precision in extrapolating from high doses in animals to lower doses in humans. Five uncertainty factors commonly used are summarized in Table 5-1.

RfDs are generally calculated using the formula:

$$\text{RfD (in mg/kg/day)} = \frac{\text{NOEL or LOEL (in mg/kg/day)}}{\text{Uncertainty Factor}}$$

If the estimated exposure exceeds the estimated acceptable intake, some adverse effects are presumed to be possible and that exposure level may be of potential concern. Conversely, if the estimated exposure is

Table 5-1

UNCERTAINTY FACTORS (MARGINS OF SAFETY) USED IN THE DERIVATION OF REFERENCE DOSES

Uncertainty Factor	Condition of Use
10	A 10-fold uncertainty factor is used with valid experimental results on appropriate durations of exposures of humans.
100	A 100-fold uncertainty factor is used when human data are not available and extrapolation is made from valid results of long-term animal studies.
1,000	A 1,000-fold uncertainty factor is used when human data are not available and extrapolation is made from animal studies of less than chronic exposure.
1-10	An additional uncertainty factor from 1 to 10 when using a lowest-observed-adverse-effect-level (LOAEL) instead of a no-observed-adverse-effect-level (NOAEL).
Intermediate uncertainty factor	Other uncertainty factors used, according to scientific judgment, when justified.

Source: EPA 1986.

less than the estimated acceptable intake, no adverse affects would be expected and the exposure level is considered acceptable. Noncarcinogenic risks are usually assessed by calculating a hazard index which is the ratio of the estimated exposure to the RfD as follows:

$$HI = \frac{LADD}{RfD}$$

where HI = Hazard Index, LADD = Lifetime Average Daily Dose (exposure), and RfD = Reference Dose (acceptable daily intake). A hazard index greater than 1 indicates that adverse effects may be possible while a value less than 1 means that adverse effects would not be expected.

In contrast to noncarcinogenic effects, for which thresholds are thought to exist, scientists have been unable to demonstrate experimentally a threshold for carcinogenic effects. This has led to the assumption by federal regulatory agencies (e.g., EPA, Food and Drug Administration [FDA], and Occupational Safety and Health Administration [OSHA] that any exposure to a carcinogen theoretically entails some finite risk of cancer. However, depending on the potency of a specific carcinogen, and the level of exposure, such a risk could be vanishingly small.

Scientists have developed several mathematical models to estimate low-dose carcinogenic risks from observed high-dose risks. Consistent with current theories of carcinogenesis, EPA has selected the linearized multistage model based on prudent public health policy (EPA 1986b). In addition to using the linearized multistage model, EPA uses the 95% upper confidence limit for doses or concentrations in animal or human studies to estimate low-dose, carcinogenic potency functions (CPFs). By using these procedures, the regulatory agencies are unlikely to underestimate the actual CPFs for humans.

Using CPFs, lifetime excess cancer risks can be estimated by:

$$Risk = \Sigma\, LADD_j \times CPF_j \qquad \text{Equation 1}$$

where $LADD_j$ is the exposure route-specific lifetime average daily dose, and CPF_j is the route-specific carcinogenic potency factor.

Some of the exposure levels estimated in this study fell above the range of doses for which the multistage model provides reliable carcinogenic risk estimates. For these exposure levels the carcinogenic risks were estimated using the one hit model. Using this method, lifetime excess cancer risks are estimated by:

$$\text{Risk} = \Sigma\ 1-e^{-CPF_j \times LADD_j} \qquad \text{Equation 2}$$

Using the multistage model, the carcinogenic risks for the three major routes of exposure are calculated as follows:

$$\text{Risk} = LADD_o CPF_o + LADD_d CPF_o + LADD_i CPF_i$$

where the subscript "o" represents the oral route, the subscript "d" represents the dermal route, and the subscript "i" represents the inhalation route. Risks are summed across routes in a similar fashion when the one hit model is used.

Once substances have been absorbed by the oral or dermal routes their distribution, metabolism, and elimination patterns (pharmacokinetics) are usually similar. For this reason, and because dermal route RfDs and CPFs are usually not available, oral route RfDs and CPFs are commonly used to evaluate exposures to substances by both the oral and dermal routes. Although inhalation route pharmacokinetics differ more from oral route kinetics than do the dermal route kinetics, oral RfDs and CPFs may also be used to evaluate inhalation exposures if inhalation route RfDs and CPFs are not available.

Since no "safe" exposure is believed to exist for carcinogens, the task becomes one of determining what level of risk will be deemed acceptable. In general, regulatory agencies in the United States (EPA, FDA, and OSHA) have not established a uniform cancer risk level for distinguishing between risks which are deemed acceptable and those which may be of concern. The agencies have generally considered risks in the range of one in ten thousand (1×10^{-4}) to one in ten million (1×10^{-7}) to be acceptable, and EPA has recently adopted a risk level of one in a million (1×10^{-6}) as a "point of departure" for selecting the risk level that will be considered acceptable (EPA 1990). Many of the potential risks associated with the facility arise from the use of groundwater containing carcinogens in the potable water supply. Therefore, the risk management decisions EPA has made in promulgating nationwide drinking water MCLs for carcinogens are particularly relevant to the question of what risk level will be considered acceptable at the Carborundum facility. Table 5-2 summarizes the existing and adopted MCLs for carcinogens found at the Carborundum facility. Also included in this table are the corresponding risk levels estimated using EPA's CPFs and the usual drinking water risk assessment assumptions that the exposed individual is a 70 kilogram (kg) man who consumes 2 liters of water per day for an entire lifetime. As shown, the risk levels associated with MCL concentrations of compounds of concern at the Carborundum facility range from 1.6×10^{-6} to 1.2×10^{-4}. Taking all of this information into account as guidance, the risk level of 1×10^{-6} adopted by EPA as a point-of-departure for distinguishing acceptable risks from those of potential concern has been selected for use as a benchmark for that purpose in this RI.

As used here, the term carcinogen means any chemical for which there is sufficient evidence that exposure may result in continuing uncontrolled cell division (cancer) in humans and/or animals. Conversely, the term noncarcinogen means any chemical for which the carcinogenic evidence is negative or insufficient. These definitions are dynamic; compounds may be reclassified any time additional evidence becomes available which shifts the weight-of-evidence one way or the other.

In this RI, chemicals have been classified as carcinogens or noncarcinogens based on weight-of-evidence criteria contained in the EPA carcinogenicity evaluation guidelines (EPA 1986b). Table 5-3 summarizes the five EPA weight-of-evidence categories. According to these EPA guidelines, chemicals in the first two groups--A and B (B_1 or B_2)--are considered human carcinogens or probable human carcinogens based on sufficient evidence and should be the subject of nonthreshold carcinogenic risk estimation procedures. Depending upon the quality of the data, group C chemicals may also be subjected to these procedures. The remaining chemicals--in groups D and E--are defined as

Table 5-2

SURVEY OF RISKS ASSOCIATED WITH MCL CONCENTRATIONS OF CARCINOGENIC COMPOUNDS IN DRINKING WATER

Compound	MCL (μg/L)	Estimated Risk
Carbon tetrachloride	5.0	1.9×10^{-5}
1,1-Dichloroethene	7.0	1.2×10^{-4}
Tetrachloroethene	5.0	7.3×10^{-6}
Trichloroethene	5.0	1.6×10^{-6}
Vinyl chloride	1.0	6.6×10^{-5}

[AD]CZ4140:D2467, #2446, PM = 38

Source: Ecology and Environment, Inc. 1989.

Table 5-3

FIVE EPA WEIGHT-OF-EVIDENCE
CATEGORIES FOR CHEMICAL CARCINOGENICITY

Group	Description
A	Human Carcinogen - sufficient evidence from epidemiological studies
B	Probable Human Carcinogen -
B_1	o At least limited evidence of carcinogenicity to humans
B_2	o Usually a combination of sufficient evidence for animals and inadequate data for humans
C	Possible Human Carcinogen - limited evidence of carcinogenicity in animals in the absence of human data
D	Not Classified - inadequate animal evidence of carcinogenicity
E	No Evidence of Carcinogenicity for Humans - no evidence of carcinogenicity in at least two adequate animal tests in different species or in both epidemiological and animal studies

Source: EPA 1986.

noncarcinogens and should be subjected to threshold-based toxicological risk estimation procedures.

Table 5-4 summarizes the EPA oral and inhalation carcinogenicity classifications, CPFs, and RfDs for the compounds of concern found at the Carborundum facility. The toxicological properties of these compounds are summarized in toxicological profiles in Appendix D.

The types of exposure that are of potential concern at the Carborundum facility are long-term, low-level exposures. Therefore, the estimated LADDs for the various pathways of exposure will be used to estimate the potential risks. This is a conservative approach since any measures taken to ensure that long-term exposures do not exceed acceptable levels will also protect against possible short-term effects since short-term effects generally occur at higher exposure levels than long-term effects.

The LADDs for the principal routes of exposure (inhalation, ingestion, and dermal absorption) are estimated based on the chlorinated organic concentrations in the exposure media and the duration of exposure. For the exposure pathways potentially of concern at the Carborundum facility, the exposure medium is the air being breathed for the inhalation route, the residential water supply and shallow sediments for the ingestion route (drinking water), and the residential water supply for dermal absorption (showering). The route-specific LADDs are estimated using the following equations.

Inhalation route:

$$LADD_i = \frac{(C_{air})(AF_i)(IR)(DED)(DE)}{(BW)(LE)}$$

Oral route (ingestion):

Drinking water:

$$LADD_o = \frac{(C_{rws})(AF_o)(VOL_{dw})(DE)}{(BW)(LE)}$$

Table 5-4

QUANTITATIVE INDICES OF TOXICITY

			Reference Doses (RfDs)			Carcinogenic Potency Factors (CPFs)		
Compound	CAS No.	EPA Weight of Evidence Category	Oral (mg/kg/d)	Inhalation (mg/kg/d)	Source of RfDs (b)	Oral $(mg/kg/d)^{-1}$	Inhalation $(mg/kg/d)^{-1}$	Source of CPFs (b)
Carbon Tetrachloride	56-23-5	B2	7.00E-04	7.00E-04 (c)	IRIS 6-30-88	1.30E-01	1.30E-01	IRIS 3-1-88
Chloroform	67-66-3	B2	1.00E-02	1.00E-02 (c)	IRIS 6-30-88	6.10E-03	8.10E-02	IRIS 6-30-88
1,1-Dichloroethane	75-34-3	C	1.20E-01	1.38E-01	EPA 1986a	9.10E-02	9.10E-02 (c)	HEAST(1989)
1,1-Dichloroethene	75-35-4	C	9.00E-01	9.00E-01 (c)	IRIS 4-1-89	6.00E-01	1.20E+00	IRIS 12-1-88
1,2-Dichloroethene (total)	540-59-0	D	2.00E-02	2.00E-02 (c)	IRIS 1-1-89	NA	NA	
Methylene chloride	75-9-2	B2	6.00E-02	6.00E-02 (c)	IRIS 3-1-88	7.50E-03	1.40E-02	IRIS 1-1-89
Tetrachloroethene	127-18-4	B2/C	1.00E-02	1.00E-02 (c)	IRIS 3-1-88	5.10E-02	1.70E-03	EPA 1986a
1,1,1-Trichloroethane	71-55-6	D	9.00E-02	3.00E-01	IRIS 6-3-88/HEA	NA	NA	
Trichloroethene	79-1-6	B2	NA(a)	NA	IRIS 6-1-89	1.10E-02	1.30E-02	IRIS 6-1-89
Vinyl Chloride	75-1-4	A	NA	NA		2.30E+00	2.95E-01	ATSDR 1988

[AD]CZ4140:D2467, #2361, PM = 7

(a) NA, not available.
(b) IRIS - EPA Integrated Risk Information System, with date of last update.
HEAST - Health Effects Assessment Summary Tables, with date of last update used (tables are updated quarterly).
HEA - Health Effects Assessment Document
EPA 1986a - Superfund Public Health Evaluation Manual
(c) Since an inhalation route-specific RfD or CPF has not been established, it has been assumed to be equal to the oral route index.

Source: Ecology and Environment, Inc.

Soil:

$$LADD_o = \frac{(C_s)(SI)(AF_o)(DE)}{(BW)(LE)}$$

Dermal route:

$$LADD_d = \frac{(C_{rws})(AF_d)(SAE)(DED)(DE)}{(BW)(LE)}$$

Where:

$AF_{i,o,d}$ = route-specific absorption factors

BW = body weight

C_{air} = compound concentration in the inspired air

C_{rws} = compound concentration in the residential water supply

C_s = compound concentration in the soil

DE = days of exposure (days in a lifetime in which exposure occurs)

DED = daily exposure duration (hours/day)

IR = inhalation rate

LE = life expectancy (days)

SAE = skin area exposed to compounds

SI = soil ingested

VOL_{dw} = volume of drinking water consumed per day

The quantitative assumptions used to estimate exposures are summarized in Table 5-5.

5.3.2 Inhalation of Volatile Chlorinated Organics by Facility Workers

High chlorinated organic concentrations were found in the soil gas at several locations around the facility; the highest concentrations were found at and around the southwest corner of the manufacturing

Table 5-5

QUANTITATIVE ASSUMPTIONS USED TO ESTIMATE EXPOSURES

Exposure Route/Parameter	Value	Reference
General Factors - All Routes		
Body Weight (kg)	70	EPA(1986a)
Length of Lifetime (years)	70	EPA(1986a)
Ingestion of Drinking Water (Domestic)		
Ingestion Rate (L/day)	2	EPA(1989)
Frequency of Exposure (days/year)	365	EPA(1989)
Exposure Duration (years)	70	EPA(1989)
Ingestion Absorption Fraction	1	EPA(1989)
Ingestion of Soil		
Ingestion Rate (mg/day)	50	E&E(1989)
Frequency of Exposure (days/year)	26	E&E(1989)
Exposure Duration (years)	10, 30	E&E(1989)
Ingestion Fraction Absorbed	1	EPA(1989)
Dermal Absorption from Water, Showering/Bathing		
Skin Surface Area Exposed (cm^2)	18,000	EPA(1989)
Duration of Shower (hours/day)	0.25	EPA(1989)
Frequency of Exposure (days/year)	365	EPA(1989)
Skin Permeability Coeff. (cm/hour)	0.001	E&E(1989)
Exposure Duration (years)	70	EPA(1988)
Inhalation-vapors: Indoor, Outdoor, Showering/Bathing		
Respiration Rate (m^3/hour)	1.2	ICRP(1984)
Duration of Shower (hours/day)	0.25	EPA(1989)
Frequency of Exposure (days/year)		
Warehouse	250	E&E(1989)
Residential Areas	365	EPA(1989)
Inactive SPDES outfall Area	26	E&E(1989)
Inhalation Absorption Fraction	1	EPA(1989)
Exposure Duration (years)		
Showering	70	EPA(1989)
Worker	10, 30	E&E(1989)
Resident	7, 30	E&E(1989)
Daily Non-showering Exposure Duration (hours/day)		
Worker	8	E&E(1989)
Resident	24	E&E(1989)

[AD]CZ4140:D2467, #2423, PM = 24

building. Individuals exposed to volatilized-chlorinated organics from this area would be expected to be the individuals maximally exposed via this pathway. The soil-gas concentrations found in this area were used to evaluate this pathway. Four compounds, 1,2-DCE, tetrachloroethene, 1,1,1-TCA, and TCE, were measured in the 1986 soil gas survey performed by Tracer Research. This soil gas data for the area around the southwest corner of the manufacturing building was supplemented by estimates of the soil gas concentrations of the other chlorinated organics (1,1-DCA, 1,1-DCE, and VC) found in the groundwater from well B-17M. Vinyl chloride is a biodegradation product of 1,2-DCE and typically has been found at one-tenth of the 1,2-DCE concentration in both soil gas and groundwater samples from the Carborundum facility. This relationship was used to estimate this vinyl chloride concentration in soil gas from the observed 1,2-DCE concentration in soil gas near B-17. Soil gas concentrations for 1,1-DCA and 1,1-DCE were estimated from their groundwater concentrations at B-17 by multiplying by the observed ratios of their soil gas to groundwater concentrations in and near B-13 during 1989-90. The B-13 area was the only location for which reasonably contemporaneous groundwater and soil gas concentrations were available.

Chlorinated organics also have been found recently (April 1990) in soil gas at sampling point DoD SG-26, slightly west of B-13. This area was considered a second potential source area for chlorinated organic vapors and the soil gas data from sampling point DoD SG-26 was used to evaluate its potential contribution to worker exposure.

Two exposure scenarios were evaluated using two exposure durations for each scenario, giving a total of four cases. The first scenario assumes the potentially exposed individual works in the southwest corner of the manufacturing area year round, 8 hours per day, 250 days per year. Chlorinated organic vapors were assumed to enter the building in two ways, in outdoor air that enters the building as makeup air and by diffusion through the floor of the building.

The outdoor air entering the building as makeup air was assumed to acquire a chlorinated organic load while passing over the high soil-gas concentration area located adjacent to the southwest corner of the manufacturing building (see Figure 4-1) and/or while passing over the second source area centered on DoD SG-26 near the western facility boundary. Because the prevailing winds at the Carborundum facility are from the southwest, both source areas are directly upwind from the manufacturing building most of the time. The fraction of this area's makeup air that passes over the southwest corner of the building was taken to be the time this area is upwind from the warehouse (i.e., the fraction of the time the wind blows from the south) times the fraction of the length of the building's south and west walls. This linear fraction of the building's south and west walls was assumed to be 120 feet/306 feet or 0.39. The average chlorinated organic concentrations in soil-gas samples SG-21, 74, 75, and 77 along with the estimated soil gas concentrations of 1,1-DCA, 1,1-DCE, and VC were used to estimate the contaminant concentrations emerging from the soil in the area in the southwest corner. The fraction of the building's makeup air that passes over the DoD SG-26 source area was taken to be the fraction of the time the wind blows from west-southwest. A near field box model and a far-field dispersion model were used to estimate the outdoor air concentrations that would result when the chlorinated organic vapors emerging from the soil mixed with the air passing over the warehouse and DoD SG-26 source areas, respectively. The resulting air concentrations were evaluated at a point 50 feet downwind from the source area adjacent to the warehouse and 400 feet downwind from the DoD SG-26 source area. These concentrations were used to estimate the chlorinated organic inputs from makeup air to the warehouse air.

The other potential chlorinated organic input to the warehouse air is diffusion of vapors directly from the soil gas, through the building's floor, and into the warehouse air. The average concentrations in soil-gas samples SG-21, 22, 74, and 75, which are all adjacent to the south side of the warehouse, were used to estimate this source. The vapors were assumed to diffuse through the area of the floor extending 10 feet in from the south edge of the building.

The second scenario assumes that the exposed individual works outside in the vicinity of the southwest corner of the warehouse six months of the year (April - September) and works in the warehouse for the other six months (October - March). While working outdoors, the individual was assumed to be located 50 feet downwind from the high soil gas concentration area and 400 feet downwind from the DoD SG-26 source area, 8 hours a day, 125 days a year.

The mathematical models used to estimate the flux of chlorinated organic vapors emerging from the soil, the air concentration downwind from the source areas, the flux of vapors through the floor of the warehouse, and the air concentrations in the warehouse are identified and briefly described in Appendix E along with the key quantitative assumptions used.

The exposure durations evaluated were 10 years, which was intended to represent a typical worker exposure period, and 30 years representing a reasonable worst case.

5.3.3 Exposure of Facility Workers to Chlorinated Organics in Shallow Sediments

Exposure of facility workers to chlorinated organics in facility sediments could occur by two mechanisms: inhalation of vapors emanating from the soil and ingestion of small quantities of the sediment as a result of direct dermal contact followed by hand-to-mouth transport. Since the chlorinated organics are volatile, they would most likely evaporate from soil on the skin faster than they would be absorbed through the skin; therefore, dermal absorption was not considered to be a significant route of exposure. The average chlorinated organic concentrations in the five sediment samples collected on the Carborundum facility (from a depth of 6 inches) during July 1989 and January 1990 were used to estimate the exposures and related risks. The exposed individual was assumed to be a worker involved in grounds maintenance who works in the area 4 hours per week for 6 months of the year (April through October). The vapor concentration in inhaled air was calculated using the same mathematical models as those used to estimate vapor concentrations near the warehouse. The amount of soil ingested was assumed to be 50 mg, an amount that might be on the inside surfaces of the thumbs and fingers, and might be transferred to articles of food or cigarettes if the workers ate or smoked without washing their hands. The exposure durations evaluated were again 10 and 30 years, representing typical and reasonable worst case exposures, respectively.

5.3.4 Inhalation of Chlorinated Organic Vapors by Residents of the DoD Housing Facility

Only one exposure scenario was evaluated for this pathway because indoor and outdoor exposures are essentially equal for the following reasons. Residences constructed before 1970, such as the DoD residences, have air exchange rates of about one exchange per hour with all windows and doors closed as in the winter. (Summer exchange rates with windows and doors open are much faster.) The compounds of concern at the DoD housing facility are vapors which can enter the residences just as readily as the general makeup air and there is no mechanism comparable to the settling out of particulates to remove them from the indoor air. Therefore, indoor and outdoor air concentrations will equalize after only a few air exchanges. Indoor air has an additional potential input in the form of vapors diffusing through the concrete pads upon which the DoD housing residences are constructed. However, the rate of diffusion through the concrete pad or through cracks or gaps in the pad is so slow that this input is orders of magnitude smaller than that from makeup air, making the diffusion input negligible and potential indoor and outdoor exposures essentially the same.

Chlorinated organic vapor contributions from two source areas were summed to estimate the average ambient air concentrations in the DoD housing area in the vicinity of well B-22M. The two source areas were the high soil gas concentration area southwest of the warehouse and the area around soil gas sampling point DoD SG-26 just west of B-13. The contributions from these areas were estimated separately because of their markedly different chlorinated organic concentrations and their different distances from the receptor area.

Soil gas concentrations were available for four chlorinated organics (total 1,2-DCE, tetrachloroethene, TCA, and TCE) for the high concentration area near the warehouse. Soil gas concentrations of 1,1-DCA, 1,1-DCE, and VC near the warehouse were again estimated as described in Section 5.3.2. Soil gas was sampled throughout the portion of this DoD housing area adjacent to the Carborundum facility during April 1990, however, chlorinated organics were detected at only one sampling location, DoD SG-26, just west of well B-13. Both the area near the warehouse and the DoD SG-26 area were considered potential sources of chlorinated organic vapors that could reach the DoD housing area. The contribution of each of these source areas to the ambient air concentrations in the DoD housing area was estimated using appropriate air dispersion models and taking into account the fraction of the time each of these source areas is upwind from the well B-22M area, based on wind rose data for Buffalo, New York.

Residents were assumed to be exposed 24 hours per day, 365 days per year. This is a very conservative (health protective) assumption since it is highly unlikely that anyone would spend this much time at home. Two overall exposure durations were evaluated: seven years, representing typical residential exposure, and 30 years, representing the reasonable worst case. The models used to estimate the rate of chlorinated organic diffusion through the soil and dispersion and transport in the ambient air are identified and briefly described in Appendix E along with the key quantitative assumptions used in evaluating the models.

5.3.5 Potential Use of Groundwater Containing Chlorinated Organics for Residential Supply Purposes

The chlorinated organic concentrations assumed to be present in the residential water supply for risk assessment purposes were derived from groundwater concentrations observed at the facility. Five cases were evaluated. Cases 1 and 2 serve to estimate the potential risks associated with the compound concentrations that have already appeared in the groundwater off site. Case 1 uses the average concentration (1988-90) in off-site wells, downgradient from the facility, and can be viewed as representing the typical risks posed by the groundwater in this area. Case 2 uses the maximum concentration observed for each chlorinated organic in this area and can be viewed as a reasonable worst case risk estimate for this area. The concentrations in wells B-21M through B-26M and B-27M through B-31M were used in evaluating Cases 1 and 2. Cases 3 and 4 serve to estimate the potential risks posed by the chlorinated organic concentrations at the facility boundary. The current average concentration (1988-89) was used in Case 3 and the maximum observed concentration for each chlorinated organic was used in Case 4 to estimate the typical and reasonable worst-case risks, respectively. The concentrations in wells B-3M through B-7M, B-9M, B-13M, B-19M, and B-27M were used to evaluate Cases 3 and 4. Finally, the maximum concentration of each chlorinated organic ever observed in the groundwater facility-wide was used as Case 5 which can be viewed as representing an extreme worst-case risk estimate for the groundwater facility-wide. When evaluating risks associated with the use of water containing chlorinated organics for residential supply purposes (drinking, showering, etc.), the duration of exposure is usually assumed to be an entire lifetime, as it was for this RI.

The majority of the risk associated with the use of water containing volatile chlorinated organics for general household purposes arises from drinking the water and showering or bathing. Drinking the water involves ingestion of the chlorinated organics, and, while showering or bathing, chlorinated organics can be absorbed through the skin from the water and inhaled from air. Chlorinated organics have a greater opportunity to volatilize from shower water than bath water; because of the greater air/water interface area available and because of the greater air turbulence due to the falling water droplets. The usual risk assessment assumption is that an individual either showers or bathes once a day. Since showering involves the greater exposure potential, it was chosen for use in the risk estimate.

Other household activities, such as washing dishes, doing laundry, washing cars, watering lawns and gardens, and using groundwater in swimming pools would also involve some exposure to chlorinated organics in the water. However, these exposures are probably much less than those associate with drinking the water and showering and therefore were not included in the residential water usage risk estimate.

The mathematical models used to estimate exposure potentially resulting from drinking, and showering, with water containing chlorinated organics and key quantitative assumptions are identified and briefly described in Appendix E.

5.4 EXPOSURE AND RISK ESTIMATES

5.4.1 Inhalation of Vapors by Facility Workers

The soil-gas and groundwater chlorinated organic vapors used and the resulting estimated air concentrations in the warehouse and in the outdoor air near the high soil gas concentration area near well B-17M are given in Table 5-6. The estimated risks associated with the estimated exposures are given in Table 5-7.

The estimated carcinogenic risks for the four exposure scenarios investigated for workers working in the vicinity of the warehouse are all less than 1 x 10^{-10} which is 10,000 times less than the benchmark risk level of 1 x 10^{-6} selected to distinguish acceptable risks from those of potential concern. This indicates that potential carcinogenic risks to site workers are well below levels that could be of concern. Similarly, the estimated hazard indices for noncarcinogenic risks to workers were all less than 1 x 10^{-8}. Noncarcinogenic adverse effects are not expected when the hazard index is less than one. In this case the hazard indices are all at least one hundred million times lower than one, therefore no noncarcinogenic adverse effects would be expected.

ARARs for air concentrations of the compounds of concern on the Carborundum facility include the OSHA limits for air contaminants in the work place. New York State allowable ambient levels (AALs) are additional guidelines applicable to the general ambient air (not just workplace air) to be considered. The values of these standards for the contaminants found in the soil gas, which were used to evaluate this exposure pathway, are summarized in Table 5-8. None of the air contaminant concentrations estimated to arise from chlorinated organics at the Carborundum facility exceeded any of the criteria concentrations.

5.4.2 Exposure of Facility Workers and the General Public to Chlorinated Organics in Shallow Sediments

The average soil concentrations and the estimated air concentrations 5 meters downwind from the inactive SPDES outfall ditch are given in Table 5-9. The estimated potential risks associated with breathing the air and ingestion of small amounts of soil through hand-to-mouth contact are given in Table 5-10. All of the estimated risks are well below the benchmark levels used to distinguish risks that may be of

Table 5-6

GROUNDWATER, SOIL GAS, AND ESTIMATED AIR CHLORINATED ORGANIC CONCENTRATIONS USED TO ESTIMATE POTENTIAL FACILITY WORKER EXPOSURES

	High Soil Gas Concentration Area Near Well B-17M				
Compound	Average Soil Gas Concentration[a] (mg/m^3)	Average Groundwater Concentration in B-17M ($\mu g/L$)	Soil Gas Concentration in DoD SG-26 (mg/m^3)	Estimated Outdoor Air Concentrations Near the High Soil Gas Concentration Area (mg/m^3)	Estimated Air Concentrations in the Warehouse (mg/m^3)
1,1-Dichloroethane	NA	135	3.5	1.91E-09	7.18E-10
1,1-Dichloroethene	NA	175	0.15	1.17E-10	4.45E-11
Total 1,2-Dichloroethene	15.6	NU	5	2.78E-09	1.05E-09
Tetrachloroethene	1.99	NU	NA	3.22E-10	1.26E-10
1,1,1-Trichloroethane	2.03	NU	0.4	3.61E-10	1.38E-10
Trichloroethene	970	NU	2	1.72E-07	6.78E-08
Vinyl Chloride	1.6[b]	NU	0.5	3.87E-10	1.46E-10

[AD]CZ4140:D2467, #2398, PM = 10

[a] Soil gas samples SG-21, 74, 75, and 77.

[b] Estimated from total 1,2-DCE soil gas concentration.

NA - Not analyzed.

NU - Not used. Groundwater concentrations were not used for compound for which soil-gas data were available.

Table 5-7

FACILITY WORKER VAPOR-EXPOSURE SCENARIO
SUMMARY OF ESTIMATED RISKS

Compound	Worker Working Inside Warehouse Year Round				Worker Working Inside Warehouse 6 Mo/Yr and Outside Near Well B-17M 6 Mo/Yr			
	10-Years Exposure		30-Years Exposure		10-Years Exposure		30-Years Exposure	
	Carcinogenic Risks	Noncarcinogen Effects Hazard Indices	Carcinogenic Risks	Noncarcinogen Effects Hazard Indices	Carcinogenic Risks	Noncarcinogen Effects Hazard Indices	Carcinogenic Risks	Noncarcinogen Effects Hazard Indices
1,1-Dichloroethane	8.75E-13	6.97E-11	2.63E-12	2.09E-10	1.60E-12	1.28E-10	4.80E-12	3.83E-10
1,1-Dichloroethene	7.15E-13	6.62E-13	2.15E-12	1.99E-12	1.30E-12	1.20E-12	3.90E-12	3.61E-12
Total 1,2-Dichloroethene	NA	7.05E-10	NA	2.12E-09	NA	1.29E-09	NA	3.85E-09
Tetrachloroethene	2.87E-15	1.69E-10	8.64E-15	5.08E-10	5.12E-15	3.01E-10	1.53E-14	9.00E-10
1,1,1-Trichloroethane	NA	6.17E-12	NA	1.85E-11	NA	1.12E-11	NA	3.33E-11
Trichloroethene	1.17E-11	NA	3.52E-11	NA	2.09E-11	NA	6.25E-11	NA
Vinyl Chloride	5.78E-13	NA	1.73E-12	NA	1.06E-12	NA	3.16E-12	NA
TOTALS	1.39E-11	9.51E-10	4.17E-11	2.86E-09	2.49E-11	1.73E-09	7.44E-11	5.17E-09

[AD]CZ4140:D2467, #2386, PM = 2

NA: Not Applicable

Table 5-8

ARARs AND OTHER CRITERIA TO BE CONSIDERED (TBC) FOR COMPOUNDS OF CONCERN IN WORKPLACE AND AMBIENT AIR

	ARARs			Other TBC Criteria
	OSHA Limits For Air Contaminants[(a)]			NYS AALS[(b)]
Compound	TWA (mg/m^3)	STEL (mg/m^3)	CEILING (mg/m^3)	(mg/m^3)
Chloroform	--	--	240	0.167
1,1-Dichloroethane	400	--	--	2.7[c]
1,1-Dichloroethene	--	--	--	0.0667
Total 1,2-Dichloroethene	790	--	--	2.63[c]
Methylene Chloride	1,750	--	3,500	0.0027
Tetrachloroethene	670	--	1,340	1.116
1,1,1-Trichloroethane	1,900	2,450	--	38
Trichloroethene	540	1,080	--	0.9
Vinyl Chloride	2	10	--	0.0004

[a] OSHA 1989

[b] New York State allowable ambient levels from NYSDEC Air Guide-1, 1985-86 edition (NYSDEC 1985).

[c] Calculated from ACGIH TLV value using the formula AAL = TLV/300.

Table 5-9

SHALLOW SEDIMENT AND ESTIMATED AMBIENT AIR CHLORINATED ORGANIC CONCENTRATIONS USED TO ESTIMATE POTENTIAL FACILITY WORKER EXPOSURE FROM CONTACT WITH THE SEDIMENTS

Compound	Average Shallow Sediment Concentration ($\mu g/kg$)	Estimated Ambient Air Concentration (mg/m^3)
Total 1,2-Dichloroethene	1,130	5.72E-07
Trichloroethene	1,500	3.63E-07

[AD]CZ4140:D2467, #2447, PM = 29

Table 5-10

FACILITY WORKER SHALLOW SEDIMENT EXPOSURE SCENARIO
SUMMARY OF ESTIMATED RISKS

	10 Years Exposure		30 Years Exposure	
Compound	Carcinogenic Risks	Noncarcinogenic Effects Hazard Indices	Carcinogenic Risks	Noncarcinogenic Effects Hazard Indices
Total 1,2-Dichloroethene	NA	4.31E-7	NA	1.29E-6
Trichloroethene	1.23E-10	NA	3.70E-10	NA

[AD]CZ4140:D2467, #2448, PM = 14

NA: Not applicable.

potential concern from risks that would generally be regarded as insignificant. Therefore, it appears that measures to reduce the risks from the shallow sediment need not be considered.

5.4.3 Inhalation of Chlorinated Organic Vapors by Residents of the DoD Housing Area

The groundwater, soil gas, and estimated ambient air chlorinated organic concentrations in the DoD housing area are given in Table 5-11. The estimated potential risks associated with breathing air with the estimated concentrations are summarized in Table 5-12.

The estimated carcinogenic risks are all at least 10,000 times less than the risk level of 1×10^{-6} selected as a benchmark for distinguishing acceptable risks from those of potential concern. This indicates that the carcinogenic risks associated with this exposure pathway are low enough to generally be considered insignificant and acceptable. The hazard indices for noncarcinogenic effects are all less than 1×10^{-8}, indicating that the occurrence of noncarcinogen adverse effects would be extremely unlikely. Since the estimated risks of both carcinogenic and noncarcinogenic effects are within the acceptable ranges, it appears that no remedial measures to reduce the risks associated with this potential exposure pathway are indicated.

There are no ARARs for air concentrations of the contaminants of concern in the DoD residential area; however, the New York State AALs may be applicable guidelines to be considered. The values of these guidelines for the chlorinated organics potentially present in the ambient air in the DoD Housing area are summarized in Table 5-8. None of the air concentrations estimated to arise from environmental chlorinated organics at the Carborundum facility exceeded any of the guidance concentrations.

5.4.4 Potential Use of Groundwater Containing Chlorinated Organics for Residential Supply Purposes

The estimated chlorinated organic concentrations in the water and in shower stall air corresponding to the five cases described in Section 5.3.4 are given in Table 5-13. The corresponding carcinogenic risks and the noncarcinogenic effects hazard indices are given in Table 5-14. As

Table 5-11

GROUNDWATER, SOIL GAS, AND ESTIMATED AMBIENT AIR CHLORINATED ORGANIC CONCENTRATIONS USED TO ESTIMATE THE POTENTIAL EXPOSURE OF THE DoD HOUSING AREA RESIDENTS

		Well B-17M Area		
Compound	Soil Gas Concentrations in DoD SG-26 (mg/m^3)	Average Groundwater Conc. at B-17M (ug/L)	Soil Gas Conc. Near B-17M (mg/m^3)	Estimated Air Conc. in DoD Housing Area (mg/m^3)
1,1-Dichloroethane	3.5	135	--	3.85E-10
1,1-Dichloroethene	0.15	175	--	1.54E-11
1,2-Dichloroethene (total)	5	NU	15.6	4.87E-10
Tetrachloroethene	NA	NU	1.99	8.16E-12
1,1,1,-Trichloroethane	0.4	NU	2.03	4.28E-11
Trichloroethene	2	NU	970	4.52E-09
Vinyl Chloride	0.5	NU	1.6[a]	6.65E-11

[AD]CZ4140:D2467, #2395, PM = 22

NA = Not Analyzed.
NU = Not Used.

[a] = Estimated from total 1,2-DCE concentration in soil gas

Table 5-12

DoD HOUSING AREA VAPOR EXPOSURE SCENARIO SUMMARY OF ESTIMATED RISKS

	Typical Risks (7 Year Exposure)		Reasonable Worst Case Risks (30 Year Exposure)	
Compound	Carcinogenic Risks	Noncarcinogenic Effects Hazard Indices	Carcinogenic Indices	Noncarcinogenic Effects Hazard Indices
1,1-Dichloroethane	1.44E-12	1.14E-10	6.17E-12	4.91E-10
1,1-Dichloroethene	7.60E-13	7.03E-13	3.25E-12	3.01E-12
1,2-Dichloroethene (total)	NA	1.00E-09	NA	4.29E-09
Tetrachloroethene	5.70E-16	3.35E-11	2.45E-15	1.44E-10
1,1,1-Trichloroethane	NA	5.87E-12	NA	2.51E-11
Trichloroethene	2.42E-12	NA	1.03E-11	NA
Vinyl Chloride	8.05E-13	NA	3.45E-12	NA
Total	5.43E-12	1.15E-09	2.32E-11	4.95E-09

[AD]CZ4140:D2467, #2393, PM = 19

NA: Not Applicable.

Table 5-13

EXPOSURE MEDIA CHLORINATED ORGANIC CONCENTRATIONS
RESIDENTIAL WATER USAGE SCENARIO

	Downgradient Offsite (Wells B21M-26M, B28M)				Facility Boundary (Wells B3M-7M, 9M, 13M, 19M, 27M)				Entire Facility (All Wells)	
	Case 1: Current (1988-90) Average Concentrations		Case 2: Maximum Observed Concentrations		Case 3: Current (1988-89) Average Concentrations		Case 4: Maximum Observed Concentration		Case 5: Maximum Observed Concentration	
Compound	Water Conc. (mg/L)	Shower Stall Air Conc. (mg/m^3)	Water Conc. (mg/L)	Shower Stall Air Conc. (mg/m^3)	Water Conc. (mg/L)	Shower Stall Air Conc. (mg/m^3)	Water Conc. (mg/L)	Shower Stall Air Conc. (mg/m^3)	Water Conc. (mg/L)	Shower Stall Air Conc. (mg/m^3)
Carbon Tetrachloride	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.40E-04	2.85E-03	1.10E-02	1.31E-01	4.60E-01	5.46E+00
Chloroform	9.10E-04	1.14E-02	6.70E-02	8.35E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.00E-01	4.99E+00
1,1-Dichloroethane	1.30E-03	1.80E-02	2.50E-02	3.46E-01	4.93E-02	6.83E-01	9.70E-01	1.34E+01	1.20E+00	1.66E+01
1,1-Dichloroethene	9.00E-04	1.31E-02	1.90E-02	2.77E-01	1.55E-02	2.26E-01	2.30E-01	3.35E+00	5.80E-01	8.46E+00
1,2-Dichloroethene (total)	2.61E-01	3.72E+00	4.40E+00	6.28E+01	3.55E+00	5.07E+01	1.10E+02	1.57E+03	1.70E+02	2.43E+03
Methylene Chloride	2.10E-03	2.95E-02	7.10E-02	9.98E-01	1.40E-03	1.97E-02	9.60E-01	1.35E+01	2.30E+00	3.23E+01
Tetrachloroethene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.00E-05	2.30E-04	2.90E-04	3.33E-03	9.90E-03	1.14E-01
1,1,1-Trichloroethane	3.00E-04	3.78E-03	1.70E-02	2.14E-01	1.95E-02	2.45E-01	1.10+00	1.38E+01	3.70E+00	4.66E+01
Trichloroethene	2.61E-02	3.28E-01	7.50E-01	9.42E+00	2.87E-01	3.61E+00	2.40E+01	3.02E+02	1.70E+02	2.14E+03
Vinyl Chloride	1.19E-02	2.10E-01	2.60E-01	4.59E+00	3.37E-01	5.94E+00	3.20E+00	5.64E+01	2.60E+01	4.59E+02

Table 5-14

RESIDENTIAL WATER USAGE SCENARIO
SUMMARY OF ESTIMATED RISKS

	Downgradient Offsite (Wells B21M-26M, B26M-31M)				Facility Boundary (Wells B3M-7M, 9M, 13M, 19M, 27M)				Entire Facility (All Wells)	
	Case 1: Typical Current (1988-90) Risk Estimates		Case 2: Reasonable Worst Case Risk Estimates		Case 3: Typical Current (1988-89) Risk Estimates		Case 4: Reasonable Worst Case Risk Estimates		Case 5: Extreme Worst Case Risk Estimates	
Compound	Carcinogenic Risks	Noncarc. Effects Hazard Indices	Carcinogenic Risks	Noncarc. Effects Hazard Indices	Carcinogenic Risks	Noncarc. Effects Hazard Indices	Carcinogenic Risks	Noncarc. Effects Hazard Indices	Carcinogenic Risks	Noncarc. Effects Hazard Indices
Carbon Tetrachloride	NP	NP	NP	NP	2.48E-06	2.73E-02	1.14E-04	1.25E+00	4.75E-03	5.22E+01
Chloroform	4.26E-06	7.74E-03	3.02E-04	5.50E-01	NP	NP	NP	NP	1.80E-03	3.28E+00
1,1-Dichloroethane	1.04E-05	8.69E-04	2.00E-04	1.67E-02	3.95E-04	3.30E-02	7.77E-03	6.49E-01	9.61E-03	8.03E-01
1,1-Dichloroethene	8.30E-05	9.11E-05	1.75E-03	1.92E-03	1.43E-03	1.57E-03	2.12E-02	2.33E-02	5.35E-02	5.87E-02
1,2-Dichloroethene (total)	NA	1.17E+00	NA	1.98E+01	NA	1.59E+01	NA	4.94E+02	NA	7.63E+02
Methylene Chloride	2.22E-06	3.11E-03	7.51E-05	1.05E-01	1.48E-06	2.07E-03	1.02E-03	1.42E+00	2.43E-03	3.41E+00
Tetrachloroethene	NP	NP	NP	NP	3.09E-08	1.56E-04	4.48E-07	2.26E-03	1.53E-05	7.71E-02
1,1,1-Trichloroethane	NA	1.49E-04	NA	8.47E-03	NA	9.71E-03	NA	5.48E-01	NA	1.84E+00
Trichloroethene	2.65E-05	NA	7.61E-04	NA	2.91E-04	NA	2.44E-02	NA	1.73E-01	NA
Vinyl Chloride	1.05E-03	NA	2.29E-02	NA	2.97E-02	NA	2.82E-01	NA	8.99E-01	NA
TOTAL	1.17E-03	1.18E+00	2.60E-02	2.05E+01	3.18E-02	1.60E+01	3.37E-01	4.98E+02	9.24E-01	8.25E+02

[AD]CZ4140:D2467, #2366, PM = 2

NA: Not applicable.
NP: Compound not present.

shown in Table 5-13, the total estimated cancer risks associated with use of contaminated groundwater from the vicinity of the Carborundum facility exceeds the benchmark level of 1 x 10^{-6}, indicating that the carcinogenic risks would be of potential concern for every case considered. The bulk of the risk was due to TCE and its degradation products 1,1-DCE and VC (mainly VC). The total hazard indices for noncarcinogenic effects also exceeded the benchmark level of 1 in all cases, indicating that adverse noncarcinogenic effects might also be possible if this water were used for residential consumption.

These findings indicate that the groundwater in the areas at and near the Carborundum facility that were evaluated is not presently suitable for use as a source of potable water due to potential adverse health effects from the chlorinated organics present. The groundwater in the vicinity of the Carborundum facility is classified GA by New York State, indicating that its best usage is as a potable water source. Information developed by Carborundum indicates that, although public water supplies are available to everyone in the area, the groundwater within a 3/4-mile radius of the Carborundum facility continues to be used as a source of potable water to a limited degree. However, groundwater is not used as a potable water source in the immediate vicinity of the facility where the chlorinated organic compounds were found. These factors suggest that remedial measures that would reduce the potential risks of using the groundwater as a possible future source of potable water must be considered in the selection of remedial measures for the Carborundum facility.

Selection of the carcinogenic risk level that will be considered acceptable is a risk management decision that rests with the responsible regulatory agency. These decisions usually take into account site-specific factors such as the likelihood of the potential risks being realized (i.e., the likelihood of the groundwater in the immediate vicinity of the Carborundum facility actually being used as a potable water source), the size of the potentially affected population, and the feasibility and cost of achieving various potential cleanup goals. As discussed in Section 5.3, sets of reference concentrations corresponding to aggregate risks equal to the benchmark levels (1 x 10^{-6} for carcinogens, hazard index of 1 for noncarcinogens) have been derived for use as reference points by the responsible agency in selecting actual cleanup goals or target concentrations. If the responsible agency wishes to use different risk levels as the thresholds of acceptability, the reference concentrations can be adjusted by multiplying or dividing by a suitable factor.

Any set of chlorinated organic concentrations which correspond to a total hazard index no greater than one and a total carcinogenic risk no greater than the designated level of acceptability (1×10^{-6} for benchmark purposes) would be suitable reference concentrations. Two such sets of concentrations have been developed. In the first set, the benchmark carcinogenic risk of 1×10^{-6} and the benchmark hazard index value of 1 have been divided equally among the carcinogenic and noncarcinogenic contaminants, respectively. In the other set, uniform contaminant concentrations were derived for the carcinogens and noncarcinogens separately, which correspond to a total carcinogenic risk of 1×10^{-6} and a total hazard index of 1. Both sets of concentrations are given in Table 5-15.

It should be recognized that these are calculated concentrations corresponding to the specified risk levels which were developed to provide a point of reference to be taken into consideration in the process of selecting actual cleanup goals. Many of these concentrations may be impossible or infeasible to achieve from a technical standpoint and many also fall below the method detection limits of standard EPA analytical methods for the compounds which would make them impossible to verify even if they were achievable. Since the chlorinated organics vary substantially in their carcinogenic and noncarcinogenic potencies (i.e., the degree of risk posed by a given concentration) and in their amenability to various potential remedial measures, it might be desirable, for reasons of technical feasibility and/or cost effectiveness, to establish cleanup goals in terms of the overall residual risk levels to be achieved rather than in terms of specific target concentrations.

Table 5-15 also includes the available Safe Drinking Water Act (SDWA) MCLs and the New York State Quality Standards for Class GA Waters, which are ARARs for the groundwater at the Carborundum facility. The responsible agency may also wish to take these values into consideration when establishing cleanup goals. The risk levels

Table 5-15

ARARs AND CHLORINATED ORGANIC CONCENTRATIONS CORRESPONDING TO BENCHMARK RISK LEVELS FOR THE GROUNDWATER AT THE CARBORUNDUM FACILITY

		Benchmark Risk Level Concentrations (μg/L)		EPA Method 8010 - Standard Detection Limits (μg/L)	ARARs and Other TBC Criteria	
Compound	Category	Equal Risk	Equal Conc.		SDWA MCL (a) (μg/L)	NYS WQS&G GA(b)(μg/L)
Carbon Tetrachloride	C	0.034	0.011	0.12	5	5
Chloroform	C	0.717	0.011	0.05	100(c)	100(c)
1,1-Dichloroethane	C	0.048	0.011	0.07	--	50(g)
1,1-Dichloroethene	C	0.007	0.011	0.13	7	0.07(g)
1,2-Dichloroethene	N	350	573	0.10	cis: 70(p) trans: 100(p)	-- 50(g)
Methylene Chloride	C	0.583	0.011	0.25	--	50(g)
Tetrachloroethene	C	0.086	0.011	0.03	5(p)	0.7(g)
1,1,1-Trichloroethane	N	1,575	573	0.03	200	50(g)
Trichloroethene	C	0.398	0.011	0.12	5	10
Vinyl Chloride	C	0.002	0.011	0.18	2	5

[AD]CZ4140:D2467, #2363, PM = 12

C: Carcinogen
N: Noncarcinogen

a: Safe Drinking Water Act Maximum Contaminant Level.
b: New York State Water Quality Standards and Guidance Values for Class GA Groundwater (NYSDEC TOGS Series 1.1.1).
c: As trihalomethanes.
g: Guidance Value (other criteria to be considered).
p: Proposed value; will become an ARAR if it is adopted as final.

corresponding to MCL concentrations of the chlorinated organics found at the Carborundum facility are summarized in Table 5-2.

5.5 SIGNIFICANCE OF THE FINDINGS

5.5.1 Human Health Effects

Inhalation of chlorinated organic vapors originating from soil or groundwater at the Carborundum facility does not appear to pose significant health risks to workers at the Carborundum facility nor to residents of the nearby DoD housing. The estimated air concentrations do not exceed applicable standards or other guidelines either at the facility or in the adjacent DoD residential area. The models and assumptions used to estimate the exposures and the corresponding potential health risks are all conservative in nature and therefore most likely overestimate the actual risks.

The groundwater in the immediate vicinity of the Carborundum facility (the area where facility-derived chlorinated organics have been found) is not known to be used as a source of potable water at this time; however, it would pose a potential threat to human health if it were to be used for that purpose. As discussed in Section 5.2.3, the groundwater in the general vicinity of the Carborundum facility has historically been of poor quality because of its naturally high mineral content, which makes it an undesirable source of potable water. This factor, together with the availability of potable water from public water supply systems in the area, makes the future use of the groundwater in the immediate vicinity of the Carborundum facility as a source of potable water unlikely.

Migration of chlorinated organics from the Carborundum facility to areas where some very limited use of groundwater for residential supply purposes may be continuing is a potential concern. The velocity of groundwater movement through the fractured bedrock aquifer in the area is apparently quite high; however, the observed extent of chlorinated organic migration is much less than might be expected based on the hydrogeological properties of the aquifer and the inherent mobility of the compounds of concern (see Section 4.4.2). This is evidently due to the extensive biodegradation of the chlorinated organics which has been observed in the groundwater at the facility. Biodegradation can be expected to limit the distances the chlorinated organics can migrate at sufficient concentration to pose a potential threat to human health.

The effectiveness of biodegradation in limiting migration can be gauged by considering the history of the usage of chlorinated organics at the facility, the hydrogeological properties of the facility and the steep concentration gradients found between wells in suspected source areas and the outlying downgradient wells. TCE, 1,1,1-TCA, and carbon tetrachloride were used at the facility. It is reasonable to assume then that releases of these materials to the ground could have begun as much as 25 years ago. The hydrogeological properties of the shallow bedrock aquifer at the facility indicate that groundwater flow velocities average about 4,000 feet per year (see Section 4.5.4). Assuming the organic carbon content in the aquifer is no more than about 1%, the retardation factors for the compounds of concern would be about 5 to 10. Therefore, based on hydrogeological considerations alone, chlorinated organics released to the ground in 1963 might be expected to have migrated 5 to 10 miles by this time. The limits of downgradient migration to the southwest have not yet been completely defined; however, the rate at which chlorinated organic concentrations decrease from the source areas to the southwest can be considered.

The approximate total chlorinated organic concentrations in wells B-8M and B-17M, located in suspected source areas, are about 55,000 and 165,000 µg/L, respectively. In contrast, the average chlorinated organic concentration in well B-29M, which is the most downgradient well to the southwest and is located about 1,200 to 1,600 feet from the suspected source areas, is about 200 µg/L. Thus, the chlorinated organic concentration in groundwater decreased by a factor of from 275 to 825 over a distance of only about 1,200 to 1,600 feet. These observations suggest that, despite the high estimated groundwater velocities at the facility, the chlorinated organics are unlikely to migrate long distances in concentrations that could pose significant risks to human health.

5.5.2 Environmental Effects

No threatened or endangered species, critical habitats, or sensitive environments are known to exist in the vicinity of the Carborundum facility.

The chlorinated organics actually found at the Carborundum facility have all been in the subsurface (soil, soil gas, or groundwater). Chlorinated organic vapors may diffuse to the ground surface and emerge into the ambient air. However, the estimated air concentrations expected to result from this process are very low and would not be expected to result in any adverse human health effects. It is also unlikely that the estimated vapor emissions would pose a significant threat to wildlife in the vicinity of the facility. The groundwater from the facility is not known to discharge to the surface close enough to the facility for its chlorinated organic concentrations to remain high enough to pose a threat to wildlife. In view of the absence of exposure pathways involving potential environmental receptors, the impact of the chlorinated organics at the Carborundum facility on the environment appears to be minimal.

5.5.3 Effects on the Public Welfare

The chlorinated organics at the Carborundum facility are primarily limited to the subsurface, and, consequently, their potential effect on public welfare appears to be limited to the impairment of the groundwater quality in the immediate vicinity of the facility. As discussed previously, the natural groundwater quality is poor due to its high mineral content and is consequently used only to a very limited extent for residential purposes in the vicinity of the facility. The chlorinated organics at the Carborundum facility further render the affected groundwater unusable as a potable water supply source due to the potential health risks associated with these compounds. Even though the natural groundwater quality is poor, the presence of chlorinated organics in groundwater in the facility area precludes its potential best use, thereby potentially impacting the public welfare.

5.6 SENSITIVITY ANALYSIS

5.6.1 Introduction

In order to evaluate the meaning of any risk assessment, one must address the sensitivity of the assumptions made, the impact of changing the magnitude of those assumptions on the risk estimates, and the relevance of the findings to real world exposures and risks. Due to the number of assumptions, data points, and calculations, a degree of uncertainty is necessarily associated with the numerical risk values in any risk assessment. Following EPA recommendations, reasonable worst-case risks and exposure assumptions were used systematically throughout the document to provide an upper-bound value below which the real risks would almost certainly fall. These assumptions systematically and intentionally bias the risk estimates upward to help ensure that risks to human health and the environment are not underestimated.

This section begins with a discussion of the assumptions used to estimate carcinogenic risks, continues with a discussion of noncarcinogenic risk estimates, and concludes with a discussion of the other major assumptions used in developing the exposure scenarios.

5.6.2 Evaluation of Carcinogenic Risk Assessment Assumptions

As determined above, the principal potential effect of concern is cancer. The compounds of concern have been evaluated by EPA according to its weight-of-evidence carcinogenicity evaluation criteria and have been placed in Category A, "human carcinogens," or Category B, "probable human carcinogens," based on sufficient data in humans and animals and insufficient data in humans, respectively (EPA 1986b). VC is categorized as a human carcinogen (Category A) based on epidemiological data.

Rodent bioassay and epidemiological studies, such as those performed for the compounds of concern, would require tens of thousands of animals or humans in order to determine whether or not a chemical may be carcinogenic at low doses. As the relationship between tumor location, time to appearance, and the proportion of animals with cancer determines the estimated carcinogenic potency factor (CPF), animal bioassay or human epidemiological data are not routinely sufficient for directly estimating a CPF at low doses. Therefore, by necessity, agencies such as EPA use carcinogenic extrapolation models for estimating a CPF at low doses. Based upon policy ground, these agencies assume that there is no threshold dose below which carcinogenic risk will not occur. This is equivalent to the assumption that every dose above zero, no matter how low, carries with it a small but finite risk of cancer. They also assume that the dose-response relationship is linear at low doses. This is contrary to approaches used for other toxic effects, because thresholds are assumed to exist.

The current model favored by EPA and certain other federal regulatory agencies is the linearized multistage model, in which the agency also applies the statistically derived upper 95% confidence bounds, rather than a maximum likelihood value for CPF (see Section 5.2 for details of the procedure). The agency has concluded, based on theoretical grounds consistent with human epidemiological and animal data, that cancer follows a series of discrete stages (i.e., initiation, promotion, and progression) which ultimately can result in the production of cancer. Consistent with this conclusion, the use of the linearized multistage model permits an estimation of a CPF (also called slope or potency) which is not likely to be exceeded if the real slope could be measured. However, compelling scientific arguments can be made for several other extrapolative models which, if used, could result in significantly reduced values for CPFs, some tens of millions of times lower than those estimated using the linearized multistage model. The one hit model used to estimate risks due to exposures above the linear range of the multistage model is one such model. Thus, the current EPA CPFs calculated in this fashion represent upper-bound values based on animal data which should not be interpreted as necessarily equivalent to actual human cancer potencies. It is this conservative value, nevertheless, that is used in this risk assessment on policy grounds for the protection of the public health. Table 5-16 summarizes the way in which carcinogenicity risk assessment assumptions will influence the estimation of risks.

5.6.3 Evaluation of Noncarcinogenic Risk Assessment Assumptions

Key assumptions used in assessing the likelihood of noncarcinogenic effects are that threshold doses exist below which various noncarcinogenic effects do not occur and that the occurrence or absence of noncarcinogenic effects can be extrapolated between species and occasionally between routes of exposure and over varying exposure durations. The threshold assumption appears to be sound for most noncarcinogens based on reasonably good fits of experimental data to the usual dose response curves. One possible exception to this is lead, which may not have a

Table 5-16

CARCINOGENICITY RISK ASSESSMENT ASSUMPTIONS THAT MAY RESULT IN OVERESTIMATION OF RISKS

- Carcinogens are assumed to have no threshold (the level at which no concentration effect would occur) below which there is no carcinogenic risk in animals or man.
- For derivation of CPFs, the linearized multistage model for high to low dose extrapolations and laboratory animal carcinogenicity data may overestimate risks; use of the statistically based 95% upper-bound confidence limit will tend to further overestimate the calculated risks.

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threshold base for its noncarcinogenic effects (EPA 1988b). However, lead was not a compound of concern at the Carborundum facility. The other assumption generally appears to be true to varying degrees. The effects observed in one species or by one route of exposure may not occur in another species or by another route or they may occur at a higher or lower dose due to differences in the pharmacokinetics (uptake, distribution, metabolism, and elimination) of a compound in different species or by different routes of exposure. The uncertainty in these assumptions is taken into account in the development of RfDs through the use of safety or uncertainty factors. The uncertainty factors used by EPA are conservative (health protective) in nature in that they tend to overestimate the uncertainties so that the acceptable RfDs selected are unlikely to be too high. Use of the resulting RfDs therefore tends to overestimate the potential for noncarcinogenic effects occurring at a given exposure level.

5.6.4 Evaluation of Exposure Assessment Assumptions

In developing the scenarios and the assumptions used to estimate risks, E & E consistently applied many other assumptions which, on the whole, will result in moderate to significant overestimates of risks for the typical receptor:

- Scenarios are based on exposure assumptions which tend to overestimate concentrations in the air, frequencies of exposure, and portions of the lifetime over which exposures are assumed to occur.
- Exposure scenarios assume 100% absorption, which may result in the overestimation of risks.
- The scenarios are based on high frequencies of exposure from birth to death over the course of a 70-year lifetime. However, factors such as work and activities outside the home most likely result in a reduction in estimated exposures and risks below the values derived in the residential drinking water and showering scenarios.

6. FEASIBILITY STUDY WORK PLAN

E & E will conduct an FS to select an appropriate remedy for the chlorinated organics in the soil and groundwater at the Carborundum facility in Sanborn, New York. The FS process will be modeled after the interim final March 1989 EPA document, Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA. In general, this process consists of two parts. The first, Development of Remedial Alternatives, sets the remedial action objectives, selects technologies capable of meeting these objectives, and assembles these alternatives into remedial action alternatives. In the second step, Detailed Analysis of Alternatives, the alternatives are evaluated according to nine specific criteria, including cost, to highlight the advantages and disadvantages of each. After this step, a remedial alternative will be selected for implementation.

Throughout the FS process (principally during the development of alternatives), the technology screening and evaluation activities completed to date by E & E and Carborundum will be incorporated and will serve to streamline the process as appropriate.

6.1 DEVELOPMENT OF ALTERNATIVES

6.1.1 Summary of Investigation

The following is a brief summary of the chlorinated organic problem on and in the vicinity of the Carborundum facility. Refer to Section 4, Nature and Extent of Contamination, for a more detailed discussion.

The primary chlorinated organics at the Carborundum facility are TCE and associated degradation products of TCE. TCE degradation products found in environmental media at the facility include cis- and trans-1,2-DCE, 1,1-DCE, and VC. Other more minor chlorinated organics found at the facility include TCA, DCA, MC, carbon tetrachloride, chloroform, and tetrachloroethene. Groundwater contained within the upper 20 feet of the Lockport Dolomite is the primary aquifer medium which has mobilized and transported the compounds of concern on and in the vicinity of the Carborundum facility. Chlorinated organics have entered the groundwater from four suspected areas which are located in the overburden and surround the manufacturing building. This conclusion has been verified from a soil-gas survey and depth-specific soil sampling in the source areas, groundwater monitoring in two of the source areas, and interviews of long-term employees from the Carborundum facility concerning TCE handling practices.

From previous investigations performed at the Carborundum facility, a considerable volume of data exists which provides important information concerning remedial alternatives that will be selected for the cleanup of the chlorinated organics. In particular, long-term pumping tests at well P-2 and P-3 have verified that groundwater extraction and treatment is a likely remedial alternative for on-site treatment of groundwater. In regard to source remediation, Carborundum has implemented a Tank Cleaning IRM to remove high levels of chlorinated organics from septic tanks which are thought to be continuing sources in two areas. In addition, a pilot-scale treatability study utilizing vacuum extraction will be implemented to determine the effectiveness of this alternative. Because of the existence of these data, the IRM, the potential treatability study, the intent of the FS work plan, and the FS report will be to evaluate and justify alternatives that are directly applicable to site remediation.

6.1.2 Identification of Remedial Action Objectives and General Response Actions

As the first step in the development of remedial alternatives, E & E will determine remedial action objectives for the Carborundum facility. These objectives will specify the compounds of concern, media of interest, exposure pathways, and remediation goals that permit a range of remedial alternatives to be developed. The goals will include the following:

- Adequate protection against ingestion of or contact with soils containing chlorinated organics;
- Minimization of damage from and adequate protection against the spread of the groundwater plume;
- Adequate protection against future ingestion of or contact with groundwater containing chlorinated organics; and
- Adequate protection against dust emissions containing chlorinated organics into ambient air.

The remedial action objectives will be set based on both the recommendations of the health-risk assessment conducted as part of the RI, as well as all chemical- and location-specific ARARs. The results of the risk assessment would most likely be used to set cleanup standards for soil (no ARARs exist), whereas drinking water standards and other water quality ARARs would likely form the remedial action objectives for the groundwater.

6.1.3 General Response Actions

General response actions describe those actions that will satisfy the remedial action objectives. They are used for organization and classification purposes in the subsequent selection of remedial technologies. General response actions may include treatment, containment, excavation, extraction, institutional actions, or a combination of these. Like remedial action objectives, general response actions are medium specific.

6.1.4 Identification and Screening of Remedial Technologies

Using the results of site investigations as summarized in the RI, E & E will identify and select technically feasible technologies to mitigate the chlorinated organic problem.

In general, applicable remedial technologies will be selected on the bases of their effectiveness, implementability, and cost. Each of these criteria are discussed below:

- **Effectiveness.** This criterion addresses both the potential effectiveness of the technologies in handling the estimated areas or volumes of media and in meeting the remediation goals identified in the remedial action objectives, as well as the potential impacts to human health and the environment during the construction and implementation phase. Furthermore, it considers how proven and reliable the process is with respect to remediating chlorinated organics in soil and groundwater.

- **Implementability.** This criterion encompasses both the technical and administrative feasibility of implementing a technology process. Technical implementability is used as an initial screen of technology types and process options to eliminate those that are clearly ineffective or unworkable at a site. Processes not able to meet location- and action-specific ARARs will be screened out. Processes requiring prohibitively extensive permitting from government agencies may also not be selected. Additionally, if sufficient treatment, storage, or disposal capacity is not available for certain off-site options, such options also may not be selected.

- **Cost.** Cost will not be used as a major factor in the selection of technologies. However, cost will be a factor in choosing between technologies that can produce similar levels of remediation.

Throughout the past year, E & E and Carborundum have been conducting a significant amount of treatment technology evaluation and screening. For instance, biological treatment has been eliminated from the screening process since TCE and its degradants, the principal contaminants at the Carborundum facility, are not readily biodegradable in a cost-effective manner. On the other hand, the preliminary screening of technologies to date suggests that physical techniques such as in situ vapor extraction (for soil remediation) and air stripping (for groundwater remediation) may be effective and appropriate remedial technologies.

Other appropriate treatment technologies such as carbon adsorption for groundwater treatment, and soil flushing, aboveground volatilization, and incineration for soil remediation, would also be considered as potential remedial technologies. The result of all previous formal and informal technology screening activities will be incorporated into the technology selection process.

6.1.5 Development of Remedial Alternatives

Technologies identified for each medium will be combined to create remedial alternatives. The remedial alternatives may address soil and groundwater as a single system reflecting the interaction between these media, or may address each medium independently as separate operable units. Between four and six facility-wide alternatives (or three to five alternatives for each medium if separate operable units are defined) will be developed. Included among these alternatives will be alternatives that contain the contaminated media, treatment alternatives, and the no-action alternative.

6.2 DETAILED ANALYSIS OF ALTERNATIVES

E & E will conduct a detailed analysis of alternatives consisting of presentation of the relevant information needed for the selection of a site remedy. The first step of the detailed analysis will be to provide a specific description of each remedial alternative. Each description will provide the details necessary for implementation of the alternative and describe ancillary activities that would be required. All action-specific ARARs would be identified at this point. In the next step of the detailed analysis, each alternative will be assessed against the nine evaluation criteria described below. The results of this assessment will be arrayed to compare the alternatives and identify the key differences between each alternative.

Criteria by which the alternatives will be assessed include the following:

- Overall protection of human health and the environment;
- Compliance with ARARs;
- Long-term effectiveness and permanence;
- Reduction of toxicity, mobility, or volume;
- Short-term effectiveness;
- Implementability;
- Cost;
- State acceptance; and
- Community acceptance.

These factors are discussed in the following section.

6.2.1 Overall Protection of Human Health and the Environment

This criterion will provide a final check to assess whether each alternative provides adequate protection of human health and the environment. The overall assessment of protection draws on the assessments conducted under other evaluation criteria, especially long-term effectiveness and permanence, short-term effectiveness, and compliance with ARARs.

Evaluation of the overall protectiveness of an alternative will focus on whether a specific alternative achieves adequate protection and will describe how site risks posed through each pathway being addressed by the FS are eliminated, reduced, or controlled through treatment, engineering, or institutional controls. This evaluation will allow for consideration of whether an alternative poses any unacceptable short-term or cross-media impacts.

6.2.2 Compliance with ARARs

This evaluation criterion will be used to determine whether each alternative will meet all of its federal and state ARARs that have been identified in previous stages of the RI/FS process.

The detailed analysis will summarize which requirements are applicable, relevant, and appropriate to an alternative and will describe how the alternative meets these requirements.

6.2.3 Long-term Effectiveness and Permanence

The evaluation of alternatives under this criterion will address the results of the remedial action in terms of the risk remaining at the facility after response objectives have been met. The primary focus of this evaluation will be the extent and effectiveness of the controls that may be required to manage the risk posed by treatment residuals and/or untreated wastes. Such an evaluation is particularly important to all alternatives.

6.2.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

This evaluation criterion will address the regulatory preference for selecting remedial actions that employ treatment technologies which permanently and significantly reduce toxicity, mobility, or volume of the chlorinated organics. This preference is satisfied when treatment is used to reduce the principal risks at a site through destruction of chlorinated organics, reduction of total mass of chlorinated organics, irreversible reduction in mobility, or reduction of total volume of media containing chlorinated organics.

6.2.5 Short-term Effectiveness

This evaluation criterion will address the effects of the alternative during the construction and implementation phase until remedial response objectives are met. Under this criterion, alternatives will be evaluated with respect to their effects on human health and the environment during implementation of the remedial action.

6.2.6 Implementability

The implementability criterion will address the technical and administrative feasibility of implementing an alternative and the availability of various services and materials required during its implementation.

6.2.7 Cost

Detailed cost analysis of the selected remedial alternatives will include the following steps:

- Estimation of capital, operations and maintenance (O & M), and institutional costs;
- Present worth analysis; and
- Sensitivity analysis.

6.2.8 State Acceptance

This assessment will evaluate the technical and administrative issues and concerns the state may have regarding each alternative.

6.2.9 Community Acceptance

This assessment will evaluate the issues and concerns the public may have regarding each alternative.

6.3 SELECTION OF REMEDY

At the completion of the detailed analysis of the alternatives, E & E will recommend the most appropriate remedial action alternative for remediation of soil and groundwater. Such an alternative will be both cost-effective and protective of human health and the environment. Most likely, a treatment alternative involving the removal of chlorinated organics in overburden source areas and the extraction and treatment of contaminated groundwater will be recommended. The areal extent of groundwater extraction beyond the boundary of the facility called for by the recommended alternative will be a risk management decision. This decision will be based on the actual impact of the off-site groundwater plumes to human health and the environment as determined by the baseline risk assessment, the effectiveness of on-site treatment (i.e. groundwater extraction and source removal) in reducing concentrations of chlorinated organics in the off-site plume, and cost comparison between extraction and treatment of groundwater in the facility and both on and off the facility.

6.4 FS FINAL REPORT

The entire FS process will be documented in a draft FS report and, following receipt of comments, a final FS report. The FS report will document the decision process used by the project team for the selection of the recommended alternative. The FS report will include a description of the technologies considered, the screening and evaluation process used, a summary of the detailed technical and cost evaluations, and the comparative evaluation of remedial alternatives.

7. CONCLUSIONS AND RECOMMENDATIONS

The purpose of this section is to develop remedial action objectives (RAOs) to present the significant conclusions from the RI, including the Risk Assessment, and to detail recommendations for additional studies. These conclusions and recommendations have been developed as a result of data which have been interpreted from site investigations performed at Carborundum from 1984 through 1990. The focus of these investigations has been to characterize the extent to which chlorinated organics have migrated through groundwater in the Lockport Dolomite and the primary hydrogeologic factors that have controlled this migration.

7.1 REMEDIAL ACTION OBJECTIVES

RAOs are site-specific cleanup goals based on recommendations of the Risk Assessment and the application of ARARs. The compounds of concern at the Carborundum facility are TCE and its primary degradation products 1,2-DCE, VC, and 1,1-DCE.

As summarized in this section and discussed more fully in the Risk Assessment, no current threat to human health is posed from the chlorinated organics which are derived from the Carborundum facility. Thus, the need for remediation at the facility is driven principally by ARARs applicable to groundwater. RAOs are developed for groundwater using chemical-specific ARARs. Practical criteria and, to a lesser extent, action- specific ARARs are used to establish clean-up goals for soils as no chemical-specific ARARs exist for soils. Action-specific ARARs for surface water and air are also identified in this section. Technically these are not RAOs as the risk assessment concludes that no threat is posed through surface water or air. However, these action-specific ARARs are presented for continuity because they must be considered in the FS and in the remedial design program.

7.1.1 Groundwater

ARARs for groundwater are the Safe Drinking Water Act MCL, MCL goals, and the New York State Water Quality Standards for Class GA waters. The RAO is that all groundwater beyond the facility boundaries comply with ARARs. Evaluation of the above-noted ARARs for groundwater is required under CERCLA and New York State Codes, Rules and Regulations Parts 700-705. However, it should be noted that many aquifer cleanups which are in progress are not attaining ARARs for groundwater. The groundwater velocity at the Carborundum site is sufficiently high to effect a relatively rapid cleanup of the bedrock aquifer. Whether the very strict MCL standards for TCE of 5 ppb and VC of 1 ppb can be attained will not be known for several years. This RAO for groundwater may need to be re-evaluated and changed to an alternate contaminant limit (ACL) should these strict cleanup standards prove to be impractical several years into remediation.

7.1.2 Soils

Assuming that an in-situ treatment technology such as vapor extraction is used for soil remediation, the RAO for soils will be determined by using the Toxicity Characteristic Leaching Procedure (TCLP) and comparing the results of the TCLP extract to MCLs.

The primary objective of this RAO is that a soil source area will be considered remediated when the TCLP extract meets or is beneath MCLs. The level of the TCLP extract may be overly conservative because it is expected that groundwater which flows through or underneath a source area is probably diluted greater than 20-fold prior to flowing off site. For instance, there is approximately an 80-fold decrease in chlorinated organics levels in groundwater from B-17M, which is screened in bedrock beneath an overburden source area, and B-23M, which is screened in bedrock and is located off site in the direction of the primary migration of the downgradient plume. Thus, while TCLP will be used as a guideline, the RAO for soils will be considered complete when it can be demonstrated that source area soils are not adversely impacting off-site groundwater at levels which exceed MCLs.

If soils containing chlorinated organics must be excavated, they will most likely be classified as a F002 listed hazardous waste under the Resource Conservation and Recovery Act (RCRA). The soils would then be classified as a RCRA hazardous waste according to the Mixture Rule (40 CFR 261.3(a)2). Following treatment, standards set to TCLP testing (i.e., 91 ppb for TCE, 410 ppb for 1,1,1-TCA, and 460 ppb for MC) must be met. Traditionally, the wastes (soils) would then be disposed of at a secure landfill following treatment. However, as defined in the "contained-in interpretation" of the Mixture Rule, there is some potential that once treated, the waste would no longer be considered hazardous and could consequently be placed into the area from which it was excavated (EPA Directive 9347.3-05FS, July 1989). (E & E is currently obtaining a memorandum from EPA regarding this issue). If possible, this would remove the step of disposing the soils in a secure landfill following treatment should excavation be necessary.

7.1.3 Surface Water

ARARs for surface water primarily focus on groundwater discharge during remediation. Potential avenues of surface water discharge and the associated ARARs are as follows:

- o Discharge to Cayuga Creek: Cayuga Creek is the nearest surface water body to the Carborundum facility. An SPDES outfall which connects the facility with Cayuga Creek has been inactive since 1983. Potentially the outfall could be reactivated if an air stripper or another mechanism of groundwater treatment is required during remediation. In this case, the water quality regulations class D streams (New York State Codes, Rules and Regulations, Parts 700-705) would be applicable. Preliminary concentrations of the compounds of concern which may be applicable to the outfall were reactivated by NYSDEC (see Table 7-1).

- o Discharge to the POTW: A second disposal route for groundwater is direct discharge to the Niagara County Sewer District 1 POTW. Carborundum has applied for a permit to discharge groundwater to the POTW. The minimum and maximum discharge rates requested are 0.25 and 2.5 lbs/day, respectively, of chlorinated organics as determined from P-2 pumping test. A specific breakdown of individual compounds for the loading estimate is presented in Table 7-2. The minimum estimate is based on a loading of 100 gpm or 150,000 gpd. The maximum estimate is based on a loading estimate of 200 gpm or 300,000 gpd.

Table 7-1

ESTIMATED CONCENTRATION LIMITS FOR DISCHARGE OF TREATED GROUNDWATER TO CAYUGA CREEK

Compound	Concentration (ppb)
Trichloroethene	10
Vinyl chloride	50
Tetrachloroethene	30
Chloroform	50
1,1-Dichloroethene	10
1,2-Dichloroethene	30
Methylene chloride	50
1,1,1-Trichloroethane	20
1,1-Dichloroethane	30

[AD]CZ4140:D2467, #3456, PM = 42

Source: Martin Doster, P.E., NYSDEC,
personal communication to
E & E, December 29, 1989.

Table 7-2

ESTIMATED LOADING FOR DIRECT DISCHARGE OF GROUNDWATER TO THE POTW

Compound	Percent of Total from P-2 Test	Minimum Loading (lbs/day)	Maximum Loading (lbs/day)
TCE	72.6	0.181	1.81
Total 1,2 - DCE	13.7	0.034	0.34
1,1,1 - TCA	5.6	0.014	0.14
$MeCl_2$	5.0	0.013	0.13
Vinyl Chloride	1.7	0.004	0.04
1,1 DCA/1,1 - DCE	1.4	0.004	0.04
TOTAL	100%	0.25 lb/day	2.5 lbs/day

[AD]CZ4140:D2467, #3457, PM = 25

- Direct discharge to aquifer: A third less likely discharge option is reinjection into the aquifer, most likely with injection wells. The ARAR for this scenario would be MCLs, MCL goals, and New York State Drinking Water Standards for Class GA waters.

7.1.4 Air

The Risk Assessment has concluded that no impact to human health through air exists from potential chlorinated organics emissions. However, air standards, as part the New York State Code of Air Regulations, Parts 212 and 221, should be applied if technologies which involve air stripping or carbon adsorption are implemented during remediation. An Application for Permit to Construct or Certificate to Operate must be completed prior to construction. Ambient guideline concentrations (AGCs) will be used to recommend emission levels. TCE and 1,2-DCE are considered moderate toxicity air contaminants whereas VC is considered a high toxicity air contaminant. AGC levels for each of these compounds are listed in the New York State Air Guide 1. Ultimately, the permitted emission levels will be established by the NYSDEC Regional Air Pollution Control Engineer, who will use Air Guide 1 when making permitting decisions.

7.2 RI CONCLUSIONS

The conclusions of the RI are as follows:

- The primary chlorinated organics which are present in groundwater at the Carborundum facility include TCE and its degradants trans-1,2-DCE, cis-1,2-DCE, VC, and 1,1-DCE. Other chlorinated organics found in the groundwater include TCA, 1,1-DCA, carbon tetrachloride, chloroform, MC, and tetrachloroethene. TCE was the primary chlorinated organic used at the facility from 1963 to 1983. TCA and carbon tetrachloride were also used in small quantities. These two compounds, their associated degradants (chloroform, 1,1-DCA, 1,1-DCE, and MC), and tetrachloroethene may have also originated from impurities in TCE which was used at the facility.

- Soil-gas surveys and surface and subsurface soil sampling have identified four source areas containing high levels of chlorinated organics in the vicinity of the manufacturing building. These include the area southwest of the manufacturing building, the area southeast of the manufacturing building, the central courtyard area of the manufacturing building, and the area on the north side of the facility parking lot opposite the northeast corner of the manufacturing building. Informal employee interviews to document past chlorinated organics handling practices have verified the likelihood of these locations being source areas. Two monitoring wells, B-8M and B-17M, which are screened in bedrock in two of these locations, provide additional credence for the belief that these locations are source areas. These two wells consistently contain the highest levels of chlorinated organics by at least one order of magnitude than the other wells on the facility (thousands of ppb versus tens to hundreds ppb).

Potentially the portion of the SPDES outfall which is located on the facility to the north of the Fiberfrax plant may be a minor source which contributes chlorinated organics to the shallow bedrock aquifer. Levels of TCE as high as 13.9 ppm and 1,2-DCE as high as 4.3 ppm have been detected in this area.

- Chlorinated organics enter groundwater directly from overburden source areas and migrate into the Lockport Dolomite, which is the primary aquifer media beneath the facility area. Groundwater, however, does not flow readily through the overburden, which is classified as an aquitard because it is composed of silts and clays of low hydraulic conductivity. The primary zone of migration within the bedrock is the upper 10 to 15 feet, which is more highly weathered and contains relatively more horizontal bedding-plane fractures than the deeper aquifer. Both of these physical factors promote greater groundwater and chlorinated organic movement than the deeper portion of the bedrock aquifer. This conclusion is verified by the three deep monitoring wells on the facility, which are screened in the first fracture zone beneath the weathered bedrock. Groundwater from two of the three wells contains low levels of chlorinated organics, generally less than 10 ppb. Only deep well B-19M contains levels of TCE and its primary degradants 1,2-DCE and VC at levels which warrant concern. By comparison, those shallow wells that are paired with each of the deep wells generally contain levels of chlorinated organics that are one to two orders of magnitude greater than the adjacent deep wells.

- The majority of chlorinated organics from the facility appear to be migrating in groundwater toward the southwest. For example, during the April 1990 groundwater sampling, concentrations of total-1,2-DCE and VC in the most downgradient off-site well to the southwest, B-29M, were 76 ppb and 2.6 ppb, respectively. For the same sampling period, wells B-22M and B-23M, located off site and nearer to the facility boundary but are still upgradient from B-29M, contain levels of 1,2-DCE between 1,000-2,000 ppb and of VC between 30 and 60 ppb. By contrast, the level of TCE in all of these downgradient wells is generally an order or magnitude less than the sum of its primary degradants 1,2-DCE and VC. Biodegradation results in the breakdown of TCE to its degradants 1,2-DCE and VC. Biodegradation, along with dispersion, appears to result in the chlorinated organics plume reaching nondetectable levels at some point between the downgradient wells and the Medina Sandstone Quarry to the west and the USGS well at the Smith Brothers farm to the southwest. Both locations are within 1.5 miles and are downgradient of the facility. Neither location yielded chlorinated organics which can be attributed to the facility. Private well and sump sampling within a 0.75-mile radius of the facility in all directions, including downgradient, yielded similar results. While low levels of common chlorinated organics were detected at eight locations, they were not attributed to the facility because they were either insignificant, found in upgradient locations, or were interpreted to be the results of outside interferences such as laboratory contamination.

In summary, chlorinated organics derived from the facility have not been detected at any sampling locations downgradient of B-29M. However, estimates of contaminant velocities in the groundwater plume and the residence time of the plume suggest that these receptors should have been impacted by the plume many years ago. This indicates that the plume is probably degraded and dispersed to nondetectable levels before its reaches receptors.

- A soil gas survey was performed at the DoD housing facility in April and May of 1990. Sampling was attempted at forty-seven sample locations; air flow was sufficient to allow sampling at 25 locations. The low permeability of the soils, probably partially caused by high levels of saturation, prevented air flow in 22 samples. Very low levels of 1,2-DCE, TCE, VC, 1,1-DCE, 1,1,-DCA, and TCA were detected in one sample obtained at 3.5 feet near the plant and housing facility boundary. The results of the survey indicate that soil gas containing chlorinated organics does not migrate to the surface in the area of the DoD facility over most of the site.

- Low levels of TCE and 1,2-DCE are migrating to the east as evidenced by the concentration detected in well B-31M. In the January and April 1990 sample, TCE was detected in this well at 9.1 and 6.9 ppb respectively. These levels barely exceed the MCL for TCE of 5 ppb. For the same sampling periods cis-1,2-DCE was well below the MCL goal of 70 ppb. While the level of TCE is of some concern, it does not appear to be impacting any nearby receptors (i.e., Cayuga Creek and residential wells) as significant levels (greater than 1 ppb) have not been detected at either of these locations.

7.3 CONCLUSIONS FROM THE RISK ASSESSMENT

Chlorinated organics have been found mainly in the groundwater and to a lesser extent in soil and soil gas at the Carborundum facility. The most significant potential pathways of exposure appear to be inhalation of chlorinated organics vapors emanating from the ground and the potential use of groundwater as a potable water source.

Potential risks associated with inhalation of vapors were evaluated for individuals working at the Carborundum facility and for residents of the adjacent DoD housing area west of the facility. The estimated risks to both groups were at least 10,000 times less than the benchmark risk level of 1×10^{-6} (one in one million) used to distinguish risks of potential concern from insignificant risks generally considered acceptable. Therefore, potential inhalation of vapors emanating from the ground at the Carborundum faculty on in the adjacent DoD housing area do not appear to pose any significant risks to human health.

The groundwater within the immediate vicinity of the Carborundum facility where chlorinated organics have been found could pose potentially substantial risks if it were to be used as a source of potable water: Within a 3/4-mile radius of the facility, groundwater is used as a potable water source by at least five residences and for other miscellaneous household purposes by other residences. However, no significant concentrations of chlorinated organics attributable to the Carborundum facility have been found in wells or basement sumps of any residences within a 3/4-mile radius of the facility.

7.4 RECOMMENDATIONS FOR ADDITIONAL STUDIES

Recommendations for additional studies to refine the extent of chlorinated organics in the various pathways and plans for IRMs are as follows:

- The majority of chlorinated organics in shallow groundwater are migrating off of the facility to the southwest. The downgradient edge of the plume migrating in this direction has not been defined beyond the area of B-29M and B-30M. These wells have been sampled two times, in both January and April of 1990. In January 1990, both wells exceeded the drinking water standard for 1,2-DCE and VC. B-29M also exceeded the drinking water standard for TCE. Levels of these compounds decreased substantially in the April 1990 sampling round. VC minimally exceeded the drinking water standard in B-29M during this sampling round. All other compounds were well below the drinking water standard. Other sampling locations which are downgradient of these two wells--the Median Sandstone Quarry,the USGS well, and the residential wells along Lockport Road--contained no chlorinated organics which are attributable to the Carborundum facility. Thus the downgradient edge of plume apparently lies between B-29M and B-30M and Lockport Road.

Additional shallow bedrock monitoring wells are needed to define the extent of chlorinated organics which may migrate from the facility. In an effort to establish locations for these wells, a comparison of 1,2-DCE and VC concentrations was made using the wells which define the primary migration path to the southwest. These included the previously mentioned downgradient wells B-22M, B-23M, B-29M, and B-30M, on-site well B-13M, and the on-site well screened beneath the source area on the southwest side of the manufacturing building - B-17M. Comparison of 1,2-DCE and VC from these wells has led to the hypothesis that a linear logarithmic decline of these compounds occurs with increasing distance from the source area. The location of the four new monitoring wells, B-32M through B-35M, is based on the prediction of where these compounds should fall below drinking water standards.

The location of the four new wells is described as follows: Monitoring well B-23M will be located approximately 2,400 feet west-southwest of the southwest facility boundary and approximately 100 feet due east of Tuscarora Road. Monitoring wells B-33M and B-34M will be approximately 1,500 feet and 2,200 feet, respectively, southwest of the southwest facility boundary. Well B-35M will be located 2,200 feet south-southwest from the southwest facility boundary and approximately 200 feet north of Lockport Road. All well locations should be regarded as tentative until permission to install wells is granted by the respective landowners.

The specific purpose of three of the wells is to monitor the outer edge of the plume with respect of drinking water standards. B-33M, however, is designed to be an intermediate monitoring point between the B-28M and B-29M locations and the B-32M, B-34M, and B-35M locations.

All of the well locations are on private property. The wells will be installed as soon as access from landowners is acquired, most likely in the summer of 1990. An additional studies report summarizing the results of the well installations and sampling will be provided following fieldwork. The wells will be incorporated into the quarterly sampling program following installation.

- The only deep monitoring well on the facility with significant levels of chlorinated organics is B-19M. Over the past four quarters of sampling (April 1989 through April 1990), levels in this well have continued to rise systematically. This may reflect a mechanical problem with the seal in the shallow bedrock such as a grout channel. Alternately, these levels may be legitimate as the well has shown good communication with the shallow bedrock aquifer during the P-3 pumping test. If possible, borehole geophysics should be completed in the well in an attempt to identify the mechanical problem. If a problem does exist, the well should be abandoned and a replacement well installed. If the levels of chlorinated organics in B-19M are legitimate, B-19M should be monitored carefully during remediation to ensure that the deeper aquifer is also remediated.

- During remediation, all wells should continue to be monitored on a quarterly basis.

- Existing potential sources of chlorinated organics influx from overburden sources into groundwater should be remediated. An IRM involving the closure of underground septic system tanks which contain high levels of chlorinated organics, chiefly TCE and 1,2-DCE, was completed in October of 1989. A pilot field study to determine if vapor extraction is an effective technology to remove chlorinated organics from overburden sources is scheduled to begin in June 1990. (Separate work plans and permits for this have been delivered and approved by NYSDEC). The study is planned in the source area at the southwest side of the manufacturing building adjacent to B-17M. This *in situ* technology may provide a cost effective means to remediate source areas in an efficient and timely manner, thus eliminating chlorinated organics influx into the bedrock aquifer and reducing the time necessary to remediate the bedrock aquifer. Technically this study is part of the Phase II RI. However, the results of this investigation will be contained in the FS, as discussed and agreed to by NYSDEC and Carborundum.

- Containment and remediation of the chlorinated organics groundwater plume directly beneath the facility and generally to the south and east can be achieved by pumping recovery wells P-2 and P-3 in unison. These wells together will generate a cone of depression which enables capture of most of the on-site and upgradient, and some of the downgradient, groundwater plume. These recovery wells will not capture chlorinated organics downgradient of the hydraulic barrier to the southwest. The southwest area is

> of concern because levels of degradant chlorinated organics (i.e., VC and 1,2-DCE) have been found above MCLs. However, analysis of the rate at which chlorinated organics concentrations in groundwater decrease to the southwest of the Carborundum facility suggests that chlorinated organics would not be expected to exceed MCLs more than 2,200 feet southwest of the Carborundum property, which is less than the distance to the closest residences in that direction. While these levels are of concern, additional extraction wells may not be necessary if the remediation program on the facility provides an effective boundary to eliminate further off-site migration of chlorinated organics beyond the naturally occurring hydraulic boundary. Based on estimates of groundwater velocity, an initial reduction in chlorinated organic concentrations should be observed in wells B-22M and B-23M within approximately one year after initiation of on-site groundwater treatment. Additional extraction wells in this downgradient area should be considered if reductions in chlorinated organics at these wells are not observed within this period.

In summary, it is felt that the on-site remediation program will effectively reduce off site levels of chlorinated organics by capture of the on-site plume which will limit further off-site migration. Direct off-site remediation involving the installation and pumping of off-site extraction wells will be required only if the newly planned monitoring wells B-32M through B-35M show significantly higher levels of chlorinated organics than are currently expected or if a risk to human health becomes evident following installation of these wells. If no apparent risk to human health is evident and the levels in these new wells are near to or below MCLs, then a phased remediation program should be implemented at the site. Under the phased program, on-site groundwater and source area remediation would be initiated, coupled with continued quarterly sitewide monitoring of the existing wells. The need for off-site remediation would then be evaluated on a yearly basis as determined by the effectiveness of the onsite program at effectively lowering the levels of chlorinated organics in the off-site plume migration. Additional studies involving the installation of an off-site capture well would be implemented if it becomes apparent that the on-site remediation program is not effective in reducing the concentrations in the off-site plume. This concept will be further evaluated in the FS.

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