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HYDROGEOLOGIC AND RELATED ENVIRONMENTAL INVESTIGATION

VOLUME I
REPORT

ECKENFELDER INC.

HYDROGEOLOGIC AND RELATED ENVIRONMENTAL INVESTIGATION

VOLUME I

REPORT

THE CIBA-GEIGY CORPORATION
TOMS RIVER PLANT
TOMS RIVER, NEW JERSEY

AWARE INCORPORATED

HYDROGEOLOGIC AND RELATED ENVIRONMENTAL INVESTIGATION

VOLUME I
REPORT

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1.0 EXECUTIVE SUMMARY

This report presents the results of a Hydrogeologic and Related Environmental Investigation of the Ciba-Geigy Corporation, Toms River Plant. The Toms River Plant, located in Dover Township, Ocean County, New Jersey, is engaged in the manufacture of dyes, epoxy resins, and various specialty chemicals. Since the inception of the site in the early 1950's, wastes generated at the facility have typically been managed on site in several distinct waste management areas. Several of these areas have released contaminants to the groundwater system.

The investigation described in this report was designed to characterize the nature and continuity of the geologic formations beneath the site, to describe the interplay of groundwater within this geologic framework, and to determine the lateral and vertical extent of contamination as a foundation for assessment of potential remedial measures. The investigation parallels, as well as supplements, the CERCLA Remedial Investigation performed by NUS on behalf of USEPA. The investigation consisted of the drilling of a total of 59 test borings and the installation of 102 monitoring wells. The borings and monitoring wells were intended to supplement the previously existing hydrogeologic database that consisted of 84 monitoring wells, 32 small diameter piezometers, and more than 150 test borings. Even with a database as large as that which now exists for the Toms River Plant, it is likely that continued data collection will occur. However, new data will surely take the form of carefully targeted studies that evaluate specific, well-defined data requirements, perhaps related to more detailed assessment of candidate remedial measures.

The investigation can be subdivided into two general categories as follows:

1. The USEPA Remedial Investigation performed by the NUS Corporation;

2. Supplemental investigations performed by AWARE, Incorporated on behalf of Ciba-Geigy.

The field program conducted by the NUS Corporation on behalf of USEPA consisted of a multi-media sampling effort designed to address the potential for contamination in groundwater, surface water, shallow soils, and stream sediment. The investigative program included the use of surface and borehole geophysical techniques, the drilling of test borings and the installation of monitoring wells, and the collection of soil, groundwater, surface water, and stream sediment samples for laboratory analysis.

In order to further define specific hydrogeologic conditions at the Toms River Plant, Ciba-Geigy supplemented the USEPA investigation with five separate and distinct investigations. Each investigation addressed a specific concern and provided additional information for the interpretation of hydrogeologic conditions. The additional investigations included:

1) a supplemental investigation in Winding River Park
2) a groundwater assessment performed under RCRA
3) an investigation of the plant perimeter
4) installation of monitoring wells in the Kirkwood No. 1 Sand, and
5) a comprehensive evaluation of the Upper Kirkwood aquitard.

In addition to the major supplemental investigations described above, several discrete investigations directed at specific data requirements were also conducted. The additional investigations included a mini-piezometer and seepage meter study of the Toms River flood plain and the active river channel, an additional terrain conductivity survey designed to supplement the survey conducted by NUS Corporation, and an investigation of the relative ages of the groundwater contained within the Cohansey and Kirkwood formations utilizing the occurrence of tritium.

These multiple investigations have culminated in a particularly clear portrayal of the hydrogeologic conditions of the Toms River Plant, per se, and the surrounding area. The basic groundwater flow regime is very well understood, as is the interrelationship between groundwater and surface water. By focusing a significant segment of the investigative effort on the question of the Toms River's role as a hydrogeologic barrier, this question has been answered with great certainty. Similarly, the spatial extent of the groundwater plume has been particularly well defined.

CONCLUSIONS

By way of summary, the following conclusions regarding the hydrogeologic and environmental conditions at the Toms River Plant site can be drawn:

1. A preliminary risk assessment has been conducted by Environ to characterize the potential risks to public health and the environment which may result from the discharge of contaminated groundwater from the Toms River Plant of Ciba-Geigy Corporation. The results are contained in a separate document entitled "Preliminary Assessment of the Risks Associated with the Ground-Water Contamination at the Toms River Plant." Environ concludes that there is no evidence that significant risk to public health would result from foreseeable exposure to contaminants migrating in groundwater from the Toms River Plant, as characterized to date, even if no remedial measures were to be instituted.

2. The plant site is underlain by a sequence of unconsolidated sediments consisting primarily of the Cohansey Sand, and the Kirkwood, and Shark River/Manasquan Formations. The Cohansey Sand and Kirkwood Formations represent the primary formation of interest. The Primary Cohansey Water-Bearing Zone is the thickest and most areally extensive of the various water-bearing zones.

3. The Cohansey Sand Formation serves as a significant aquifer in the Toms River region. Groundwater contained within the Cohansey discharges primarily to the Toms River and the associated flood plain. It has been demonstrated that the Toms River and its associated flood plain serve as a hydrogeologic barrier to northeasterly flow of groundwater within the Cohansey Sand aquifer.

4. The Kirkwood Formation forms a continuous aquitard of relatively low permeability beneath the site and serves to restrict, to a degree, the vertical movement of contaminants. The Kirkwood Formation can be

subdivided into two water-bearing zones and three interbedded aquitards. The two water-bearing zones have been termed the No. 1 and No. 2 Sands.

5. A plume of groundwater contamination has been found at the Toms River site, stretching from a north/south trending line of source areas to the Toms River. The plume encompasses a total area of approximately 375 acres.

6. The composite plume is principally found within the Primary and Upper Cohansey Sand aquifer. The plume also occupies a portion of the Lower Cohansey aquifer. A variety of contaminants or indicators of contamination have been detected within the plume, and consists largely of volatile organic compounds, as well as base/neutral extractable compounds. The inorganic constituents include chloride, sulfate, total dissolved solids and specific conductance.

7. The portion of the plume within the Lower Cohansey Sand Aquifer extends from the southern portion of the Process Area eastward to the Toms River, covering an area of approximately 100 acres. The Lower Cohansey plume discharges fully to the Toms River and its associated flood plain. However, in the area of RI-9, the plume passes the center line of the Toms River due to the combined effects of the westward meander of the river in this area and the semi-confining properties of the Cohansey/Kirkwood Transitional Unit. As a result of the discharge of the plume back to the Toms River, its eastward migration has been halted.

8. Sampling and analysis of the Toms River water has shown that the Toms River Plant has a negligible impact on the surface water quality in the Toms River. Priority pollutant organics were not found above the detection limit with the exception of trichloroethene which was found at several stations at concentrations below the detection limit. The analysis of NUS sample SW-6 indicated a concentration of 5.6 ppb. Several surface water stations suggest that iron, sodium, and calcium may be slightly elevated with respect to upstream conditions; however, this may be a natural phenomenon. Surface water and sediment samples were also collected under the direction of Environ in an area of groundwater discharge in the marshland area of Winding River Park. These samples indicate the presence of volatile organic contamination of surface water and sediment in an area which coincides with the highest isoconcentration contours of total volatile priority pollutants. One stream bed sediment sample in the vicinity of RI-9 also indicated volatile organic contamination as a result of contaminated groundwater discharge.

9. No groundwater contamination has been detected in either the No. 1 or No. 2 Sands of the Kirkwood Formation. In fact, groundwater dating employing the naturally-occurring environmental isotope, tritium, indicates that the groundwater within the Upper No. 1 Sand predates inception of the Toms River Plant operations.

10. Beneath a number of contaminant source areas, particularly the Former Landfill, the Treatment Plant Area, and the Former Fire Prevention Training Area, the presence of soil contamination as a result of the migration of dense non-aqueous phase liquids is directly or indirectly evidenced.

11. Five purge wells were activated in January 1985, on its property near the Cardinal Drive boundary in order to prevent further off-site contaminant migration in the Primary Cohansey Sand. The effectiveness of the purge system for plume capture has been evaluated via water level measurements at all available monitoring wells and piezometers completed in the Cohansey. The resulting capture zone is determined to be of sufficient width to intercept the general limits of groundwater contamination in this area. Furthermore, a pronounced groundwater divide has been created between the three easternmost purge wells and the site boundary (Cardinal Drive) such that a groundwater reversal (groundwater flow to the west) is occurring. This phenomenon clearly demonstrates that the purge wells are effective and no further off-site contaminant migration is occurring in the area.

12. The factors believed to be most significant to the selection of a site-wide remediation are as follows:

- The Toms River and its associated flood plain serve as a hydrogeologic boundary for groundwater flow in the Cohansey sand aquifer.

- The Toms River Plant site is continuously underlain by an aquitard which is part of the Kirkwood formation.

- No evidence of groundwater contamination in the Kirkwood No. 1 Sand has been found. Five additional wells have been installed in the Kirkwood No. 1 Sand for monitoring purposes.

- The presence of non-aqueous phase liquids has been indicated.

2.0 INTRODUCTION

This report presents the results of a Hydrogeologic and Related Environmental Investigation of the Ciba-Geigy Corporation, Toms River Plant. The Toms River Plant, located in Dover Township, Ocean County, New Jersey, is engaged in the manufacture of dyes, epoxy resins, and various specialty chemicals. Since the inception of the site in the early 1950's, wastes generated at the facility have typically been managed on site in several distinct waste management areas. Several of these areas have subsequently been shown to have released contaminants to the groundwater system.

The investigation described in this report was designed to characterize the nature and continuity of the geologic formations beneath the site, to describe the interplay of groundwater within this geologic framework, and to determine the lateral and vertical extent of contamination as a foundation for assessment of potential remedial measures. The actual investigation parallels as well as supplements the CERCLA Remedial Investigation perfomed at the site by the NUS Corporation on behalf of USEPA. Geologists from AWARE, Incorporated, for example, observed the field investigation conducted by NUS, retained samples for analysis, and provided an independent interpretation of subsurface conditions. In response to preliminary interpretations of the data generated during the NUS investigation, a series of supplemental studies, ultimately of comparable scope to the NUS investigation, were conducted. In the spirit of cooperation and in the belief that decisions regarding the feasibility of remedial measures should be based upon the best possible understanding of site conditions, data independently generated by Ciba-Geigy has been made available to the USEPA/NUS project team.

Even with a database as large as that which now exists for the Toms River Plant, it is likely that continued data collection will occur. New data will surely take the form of carefully targeted studies that evaluate specific, well-defined data requirements, perhaps related to more detailed assessment of candidate remedial measures. However, there can be little doubt, regarding the basic features of the physical system that control the directions and rates of groundwater and contaminant flow.

In the sections that follow, the physical layout, environmental setting and a brief history of the Toms River Plant are described. The methods and procedures utilized during the initial and supplemental investigations are outlined in Sections 4.1 and 4.2. The findings are presented in Sections 4.3 and 4.4. In Section 5.0 the implications of the findings with respect to the assessment of potential remedial measures are discussed. Section 6.0 summarizes the conclusions regarding site conditions.

3.0 SITE CHARACTERISTICS

3.1 Site History and Description

In this section the location, physical features, and a brief history of the Toms River Plant site are presented.

3.1.1 Location

The Ciba-Geigy Corporation Toms River Plant is located in Dover Township, Ocean County, New Jersey (Figure 3-1). The site encompasses approximately 1,300 acres and is situated about one mile west of the Garden State Parkway. The center of the site is situated at approximately N 39° 59' 10" latitude and W 74° 14' 20" longitude. The site is bounded by the Toms River on the northeast, by Cardinal Drive on the east, by Route 37 and residential/commercial development to the south and west, and by Pine Lake Park, a residential development, to the north. Winding River Park, an outdoor recreational area, borders the Toms River to the east and southeast of the site. The central business district of Toms River is located approximately three miles to the southeast of the site; an industrial park adjoins the site on the west. A residential area, including two senior citizen developments, is located about one mile south of the site.

3.1.2 Site Layout

The approximate limits of the Toms River Plant property are indicated on Figure 3-1. Approximately three-hundred-twenty (320) acres of the 1,300-acre site are developed; the remainder is largely wooded pineland. The developed area includes the manufacturing or process area of the facility, a wastewater treatment plant with a capacity of 7.5 million gallons per day (MGD), and a lined reservoir for emergency storage of wastewater. The bulk of the developed area is located nearly in the center of the property; the surrounding woodland thus serves as a buffer between the active portion of the facility and the surrounding land uses.

The site ranges in elevation from a maximum of about 70 feet above mean sea level in the extreme western area to less than 20 feet above mean sea level adjacent to the Toms River. The site slopes gently to the northeast, east, and southeast, before dropping off sharply towards the river in the northeastern section. Except for the wooded area in the northwest and the non-contiguous area east of Oak Ridge Parkway, the entire property is fenced.

3.1.3 Site History

CIBA States Limited began construction of the Toms River Division of CIBA States Limited in 1949. Operation of the facility was initiated in 1952 with the production of vat dyestuffs. In 1955, the Toms River Division of CIBA States Limited merged with Cincinnati Chemical Works to become Toms River-Cincinnati Chemical Corporation. Cincinnati Chemical Works, owned by the firms of Chemical Industry Basle, (CIBA), J.R. Geigy, S.A., and Sandoz Limited produced azo dyestuffs and intermediates. The azo manufacturing operations of Cincinnati

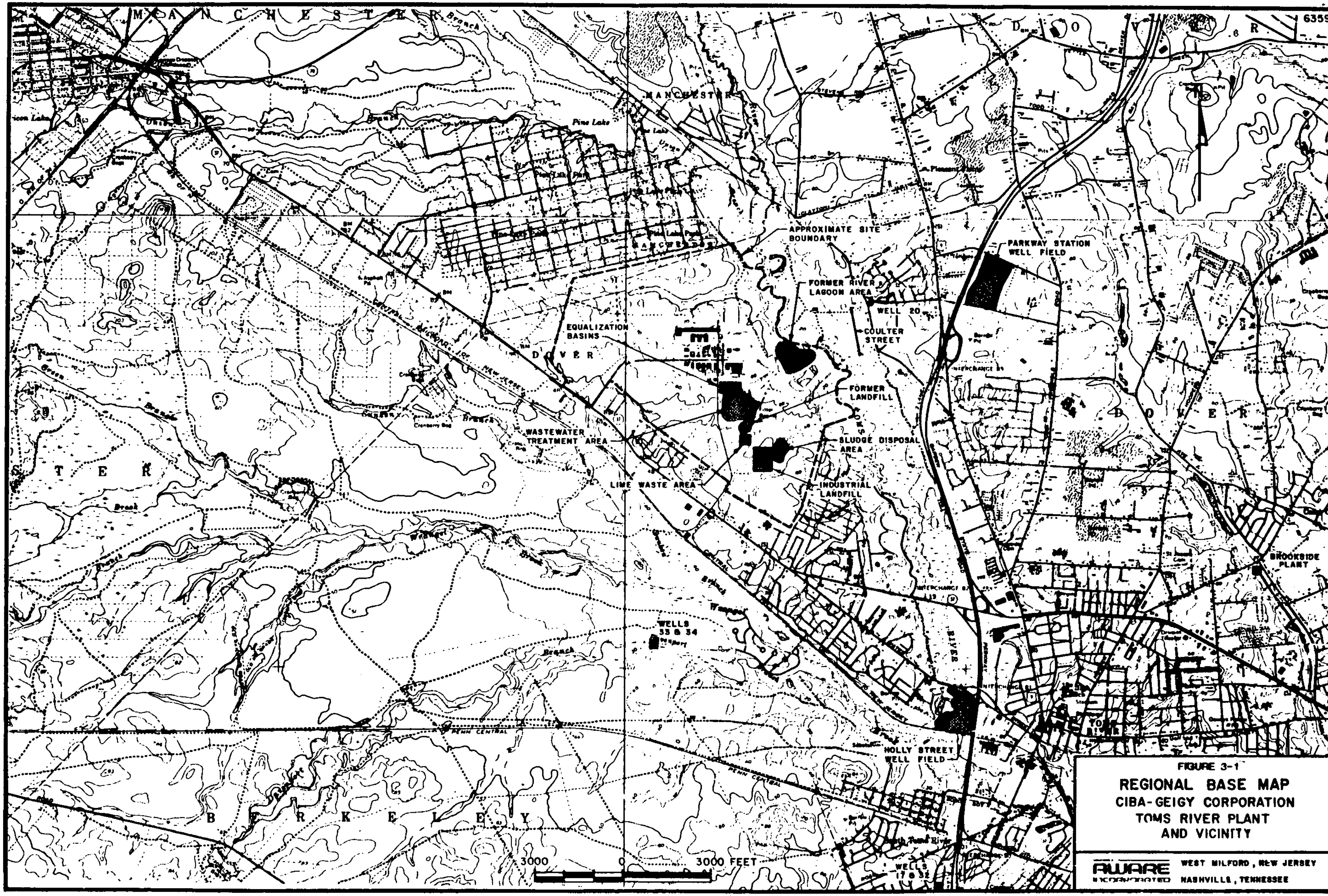


FIGURE 3-1
REGIONAL BASE MAP
CIBA-GEIGY CORPORATION
TOMS RIVER PLANT
AND VICINITY

Chemical Works were subsequently moved to the Toms River Plant during late 1959 and early 1960. Production of epoxy resins also commenced at this time at a CIBA-owned facility at the site. On June 1, 1960, Toms River-Cincinnati Chemical Corporation became Toms River Chemical Corporation owned by CIBA States Limited (which became CIBA Corporation in 1961), Geigy Chemical Corporation and Sandoz, Limited. On October 21, 1970, CIBA Corporation and Geigy Chemical Corporation merged to form CIBA-GEIGY Corporation. On November 2, 1981, CIBA-GEIGY Corporation acquired Sandoz's interest in Toms River Chemical Corporation, which thereafter was merged into CIBA-GEIGY Corporation.

The Toms River Plant manufactures dyes for the textile, paper, leather and automotive industries and epoxy resins and additives for plastics, coatings and high-performance lubricants for the construction, electronics and automotive industries.

3.2 Environmental Setting

3.2.1 Land Use

Although, originally founded in a relatively undeveloped area, the Toms River Plant has seen rapid development around its perimeter in the intervening years. This development is characterized by residential development, recreational areas, small commercial establishments, and light industrial complexes as shown in Figure 3-2. The commercial areas are located primarily along New Jersey Route 37 to the southwest of the site. The area west of the plant is zoned for industrial use, including light manufacturing and warehousing operations. Winding River Park, a greenbelt park located along the Toms River to the east of the site, is used year-round by area residents.

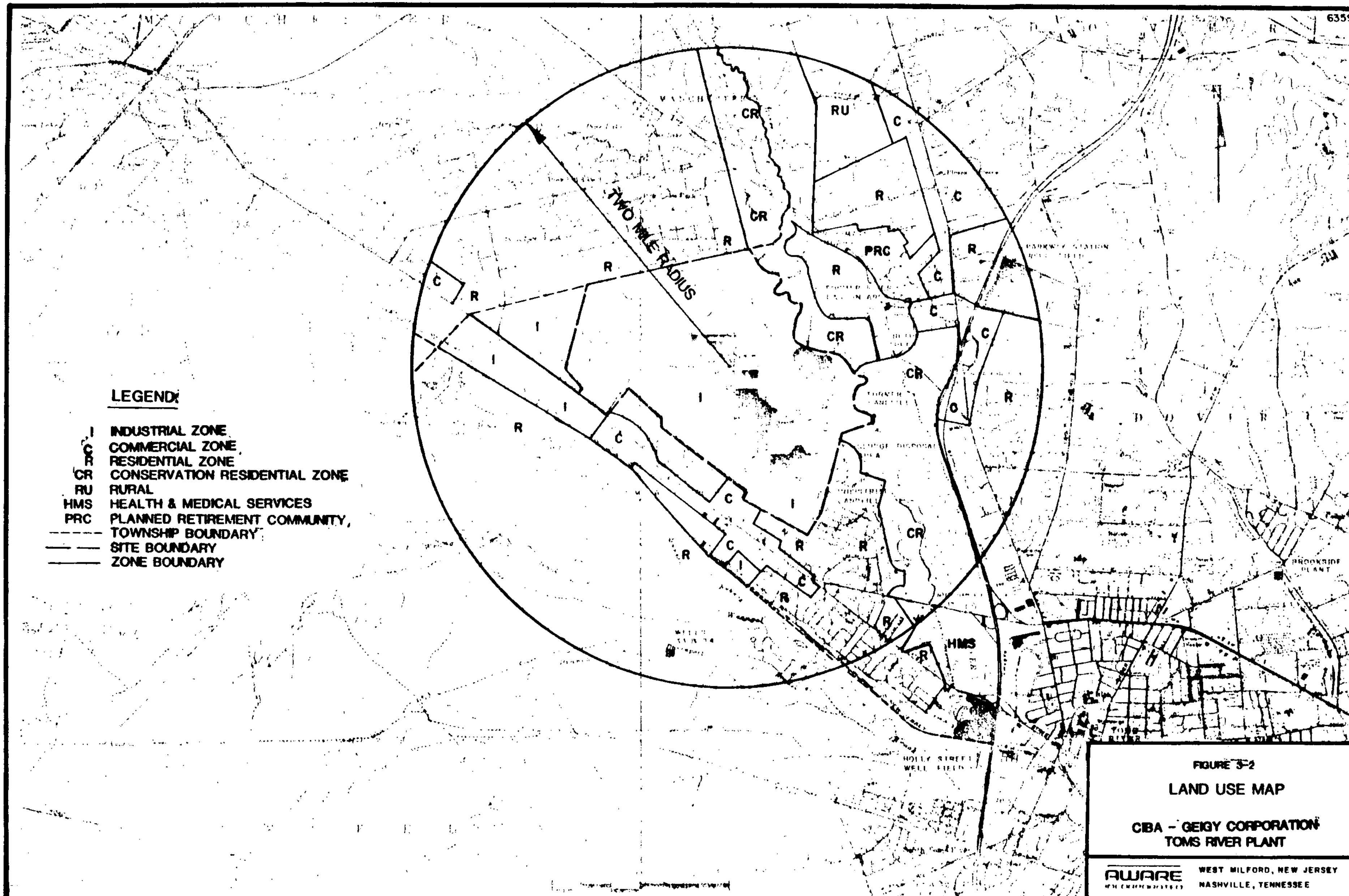
Residential areas of Dover Township are supplied with water from the Toms River Water Company which maintains 20 wells to the north, northeast, and southeast of the Toms River Plant. Dover Township is connected to the county sewer system. Residences in the Pine Lake Park area of Manchester Township are supplied by private wells and use septic systems.

3.2.2 Climate and Meteorology

Monthly climatological data for temperature and precipitation at Freehold, New Jersey are presented in Table 3-1. The measuring station for these data is located in Monmouth County, twenty miles north of the Toms River Plant site. Climatological data for precipitation at Toms River are presented in Table 3-2; temperature, however, is not measured at the Toms River station. The climate of this part of the state is characterized as continental; however, proximity to the Atlantic Ocean results in modifications to the overall temperature, wind, and rainfall patterns.

Table 3-1 indicates that temperatures at the Freehold station range from an average high of 74.2°F in July to an average low of 30.5°F in January. The average annual temperature at Freehold is 52.7°F. Temperatures at Toms River generally follow the same general pattern as those recorded at Freehold.

Precipitation totals generally are evenly distributed throughout the year. Toms River registers its highest average monthly precipitation total in August (4.98 inches) and its lowest in June (3.41 inches). However, year-to-year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TWO MILE RADIUS
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O
HMS
LEGEND:
I INDUSTRIAL ZONE
C COMMERCIAL ZONE
R RESIDENTIAL ZONE
CR CONSERVATION RESIDENTIAL ZONE
RU RURAL
HMS HEALTH & MEDICAL SERVICES
PRC PLANNED RETIREMENT COMMUNITY
TOWNSHIP BOUNDARY
SITE BOUNDARY
ZONE BOUNDARY
HOLLY STREET WELL FIELD
FIGURE 3-2
LAND USE MAP
CIBA - GEIGY CORPORATION
TOMS RIVER PLANT
AWARE
WEST MILFORD, NEW JERSEY
NASHVILLE, TENNESSEE

TABLE 3-1

AVERAGE MONTHLY TEMPERATURE AND PRECIPITATION
FREEHOLD, NEW JERSEY
(1951-1980)

Month	Temperature (°F)	Precipitation (in)
January	30.5	3.55
February	32.0	3.28
March	40.1	4.44
April	50.8	3.66
May	60.6	3.75
June	69.5	3.47
July	74.2	4.04
August	72.9	4.64
September	66.2	3.67
October	55.4	3.52
November	45.4	3.96
December	34.6	3.91
Annual	52.7 (Avg.)	45.89 (Total)

SOURCE: NOAA, 1982.

TABLE 3-2

AVERAGE MONTHLY PRECIPITATION
TOMS RIVER, NEW JERSEY
(1951-1980)

Month	Precipitation (in)
January	3.55
February	3.42
March	4.28
April	3.95
May	3.61
June	3.41
July	4.65
August	4.98
September	3.78
October	3.91
November	3.92
December	4.22
Annual	47.68 (Total)

SOURCE: NOAA, 1982

variations in the amounts recorded in late summer and early autumn may result from the northward passage of storms originating in the tropics. In years that these seasonal storms are experienced, annual precipitation totals tend to be higher than normal.

3.2.3 Surface Waters

The Toms River Plant's eastern property border lies approximately between the 8.25 and 9.75 mile marks on the Toms River. The river originates in Millstone Township, Monmouth County, and empties into Barnegat Bay. No other perennial surface waters are found on the property. The river's flow originates mainly from the water table aquifer and has low pH, hardness, and total solids concentration. The total area of the Toms River drainage basin is 190 square miles (OCPB, 1978). The Toms River is classified as FW-2, non-trout.

A gage station is situated near the Oak Ridge Parkway Bridge and downstream of the cooling water intake and discharge points (USGS, 1982). The drainage area at this point is 124 square miles. The average discharge for the past 53 years is 216 cubic feet per second (140 MGD), equivalent to 23.67 inches of precipitation per year over the drainage basin. Typical seasonal stream flow variations are evident with low flows occurring in late summer and early fall and higher flows common in late winter and early spring. Groundwater base flow is estimated to be approximately 68% of mean annual stream discharge (Anderson and Appel, 1969); accordingly, computed base flow is on the order of sixteen inches per year.

A flood plain study for the Toms River was prepared for the Ocean County Planning Board by the Philadelphia District of the U.S. Army Corps of Engineers. The study, which included consideration of tidal influences, developed the different flood elevations for the USGS stream gage located approximately 200 feet downstream of the Oak Ridge Parkway bridge. The flood crest elevations for the gage location were estimated to be as follows:

- Standard Project Flood = 26.5 feet above mean sea level;
- New Jersey Flood Hazard Area Design Flood = 21.8 feet above mean sea level; and
- New Jersey Floodway Design Flood = 20.6 feet above mean sea level.

The New Jersey Flood Hazard Area Design Flood is equivalent to a flood with a discharge 25% greater than the 100-year flood. The New Jersey Flood Hazard flood has a crest elevation of approximately 21.8 feet above mean sea level.

3.2.4 Site Drainage

Three gently sloping drainage swales convey stormwater run-off on the Toms River Plant site. An intermittent stream course crosses the borrow area in the northern sector of the property, a drainage swale exits the plant site near the intersection of Cardinal Drive and the Oak Ridge Parkway, and another channel system drains the southeastern sector of the site. Inspection of these drainage swales indicates that little, if any, surface run-off discharges from the site. The swales thus appear to serve essentially as recharge basins for the groundwater system. Permeability characteristics of on-site soils range from moderately to excessively well drained on the higher ground to poorly drained along the river.

3.3 Potential Contaminant Source Areas

In conducting a hydrogeologic investigation, it is helpful to know the location of all past or present (waste or product) storage or disposal areas, irrespective of whether they are known to or are even suspected of having contributed to groundwater contamination. The storage or disposal areas at the Toms River Plant, some of which clearly have resulted in groundwater contamination, others for which no evidence of contaminant migration has been observed, include the following:

- Former Sludge Disposal Area
- Former Landfill
- Former Lime Waste Area
- Former River Lagoon Area
- Treatment Plant Area
- Compactor Area
- Former Calcium Sulfate Disposal Area
- Former Fire Prevention Training Area
- Equalization Basins
- Process Area (Sewers and Underground Tanks in Particular)

Figure 3-3 illustrates the locations of various site features. The current operational status and background information on the potential source areas are presented in Table 3-3.

The Double-Lined Landfill, shown on Figure 3-3, does not currently represent a source of groundwater contamination. The data that support this conclusion include the results of the routine monitoring program conducted at the facility, the findings of a recently completed terrain conductivity survey in the vicinity of the landfill, and the absence of the tracer compound lithium in the appropriate monitoring wells. In addition, isoconcentration maps for several compounds do not indicate an impact from this facility. The isoconcentration maps are presented in Section 4.4.2. Accordingly, no further consideration of the Double-Lined Landfill in this report is warranted.

In a number of the potential source areas identified above, there is also a potential for the existence of non-aqueous phase liquids. If present beneath the disposal areas, per se, non-aqueous phase liquids would represent another "source" of contaminants. The following discussion addresses the mechanisms of non-aqueous phase liquid occurrence and migration, and summarizes the evidence for their existence.

When non-aqueous phase liquids are released, they migrate vertically downward through the unsaturated zone, coating soil grains in their passage. Soil has a certain capacity to attenuate non-aqueous phase liquids as a pellicular film on the individual soil grains. However, if the amount of non-aqueous phase liquids exceeds the adsorptive capacity of the soil in the unsaturated zone, the waste liquid will reach the groundwater table. The depth of penetration of the

TABLE 3-3

POTENTIAL CONTAMINANT SOURCE AREAS

Potential Contaminant Source Area	Status of Background Information
Former Sludge Disposal Area	Inactive; contains treatment plant sludge excavated from sludge drying beds and from lagoons formerly located at the site of the present wastewater treatment plant; sludge was generated between 1952 and 1976; covered with soil and vegetated.
Former Landfill	Inactive; contains wide variety of industrial wastes in bulk and in drums; capped with 30 mil PVC liner, and two feet of vegetated soil.
Former Lime Waste Area	Inactive; contains lime with calcium arsenite; capped with 30 mil PVC and vegetated.
Former River Lagoon Area	Inactive; site of three wastewater lagoons and two sludge drying beds; much of sludge from the three lagoons was hydraulically removed, filtered, and placed in the double-lined landfill in 1978; residual sludge remains in the two sludge drying beds which were covered with clean soil.
Treatment Plant Area	Site of former treatment plant; current treatment plant consists of concrete tanks; evidence of soil contamination from former unlined lagoons exists in the area.
Compactor Area	Inactive; contains predominately construction debris although the presence of industrial wastes is also possible.
Former Calcium Sulfate Disposal Area	Inactive; contains calcium sulfate sludge; covered with soil.
Former Fire Prevention Training Area	Inactive; oils and solvents were burned in kettles in this area.

TABLE 3-3 (con't)

POTENTIAL CONTAMINANT SOURCE AREAS

Potential Contaminant Source Area	Status of Background Information
Equalization Basins	Active; receives process wastewater and stormwater runoff prior to treatment.
Process Area	Active; potential specific source areas include sewers, underground storage tanks, and waste storage areas.

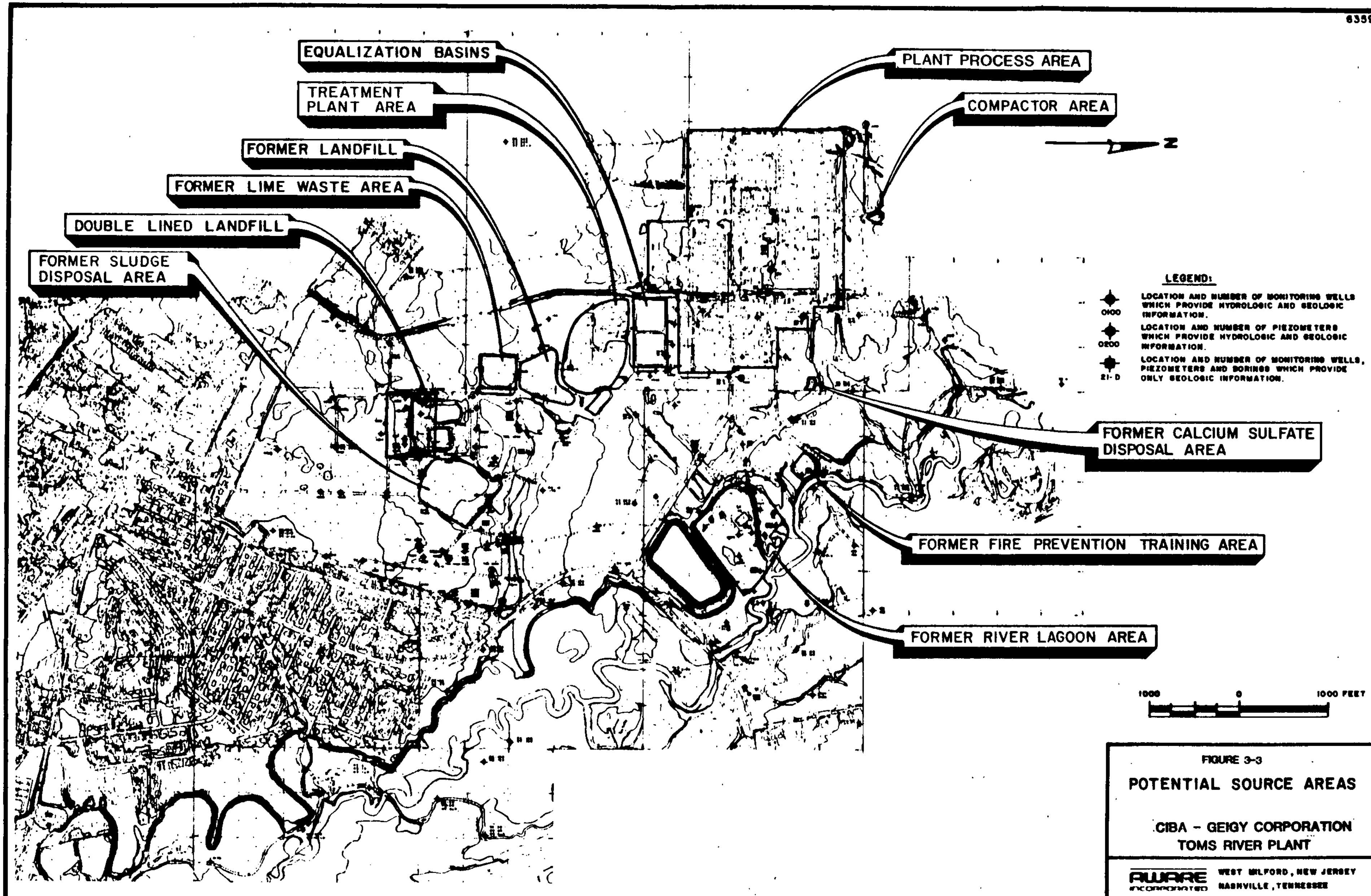

FIGURE 3-3

POTENTIAL SOURCE AREAS

CIBA - GEIGY CORPORATION
TOMS RIVER PLANT

AWARE INCORPORATED WEST MILFORD, NEW JERSEY NASHVILLE, TENNESSEE

CIB 004 1834

organic in the unsaturated soil can be estimated with the following simple formula (Vanloocke, 1975).

$$D = \frac{KV}{A}$$

Where:

D = Maximum depth of penetration, m
V = Volume of infiltrating liquid, m^3
A = Area of infiltration, m^2
K = Constant, depending on retention capacity of the soil and the viscosity of the liquid

Typical values of K are presented in Table 3-4.

Upon reaching the groundwater table, non-aqueous phase liquids which have a lower specific gravity than water (light non-aqueous phase liquids) tend to float on the groundwater table and migrate slowly downgradient atop the water table and any capillary zone that might exist. Fluctuations in the water table cause smearing of the light non-aqueous phase liquids over additional aquifer material. Eventually any free light non-aqueous phase liquids become adsorbed to the aquifer matrix.

Non-aqueous phase liquids with a higher specific gravity than water (dense non-aqueous phase liquids) will continue to sink below the groundwater table, and will continue to coat the soil grains below the zone of saturation. Dense non-aqueous phase liquids in this form are termed "residual" and represent a potential source of contamination to groundwater flowing through the soil. The dense non-aqueous phase liquids will sink through the aquifer, adhering to the grains of soil until such time as the total adsorptive capacity of the soil is sufficient to prevent further migration. If this adsorptive capacity is exceeded, the dense non-aqueous phase liquids will accumulate or "pool" at the base of the aquifer and may move laterally atop the underlying aquitard, accumulating in any depressions which may exist in this structural surface. Throughout this process of attenuation, groundwater and infiltrating precipitation will leach contaminants from the contaminated soils. This dissolved contamination will then move with the flow of groundwater producing a plume of groundwater contamination.

Definitive evidence of the occurrence of pooled, non-aqueous phase liquids is seldom found due to its limited and localized areal extent. Unless the pool is quite large, detection in a given test boring is statistically unlikely. Nonetheless, an understanding of the mechanics of formation of non-aqueous phase liquids and the history of operation of major industrial facilities that utilize solvents leads to the conclusion that the presence of residual and pooled non-aqueous phase liquids is likely at the Toms River Plant site. Together with several lines of indirect evidence of their occurrence, in fact, their absence would be most unusual.

Evidence for the presence of either residual or residual and pooled non-aqueous phase liquids at the Toms River Plant site is convincing. It should be noted that the existence of pooled, non-aqueous phase liquids would, necessarily, imply their existence in the residual form. The following discussion summarizes the currently available evidence for the presence of non-aqueous phase liquids.

TABLE 3-4

TYPICAL VALUES FOR K

Soil	K		
	Gasoline	Kerosine Gasoil	Fuel Oil
Stone, coarse gravel	400	200	100
Gravel, coarse sand	250	125	62
Coarse sand, medium sand	130	66	33
Medium sand, fine sand	80	40	20
Fine sand, silt	50	25	12

Evidence for the existence of residual non-aqueous phase liquids includes both indirect and direct evidence as follows:

1. Usage - The Former Landfill, the Treatment Plant Area, the Process Area, and the Former Fire Prevention Training Area are areas where solvents may have been used or handled. The release of denser than water organic solvents to the ground would provide a mechanism for the migration of dense, non-aqueous phase liquids in both the unsaturated and saturated zones.

2. Field Observations - Several auger borings performed at the Former River Lagoon Area, the Treatment Plant Area, and the Former Sludge Disposal Area encountered visibly-contaminated native soils beneath the apparent base of the disposal or treatment facility. The soils were visibly stained, were found both above and below the water table, and typically provided a positive HNU response. Laboratory analyses of a granular material found within the well screen of former monitoring well 744-0111 indicate the presence of individual organic constituents near or above the one percent level. Moreover, the PVC well casing at this location was found to be altered by the passage of high-strength organic liquids. These findings represent direct evidence of residual non-aqueous phase liquids. The well 744-0111 analyses are described in Section 4.12.

3. Concentrations in Groundwater - The presence of dissolved organic constituents in groundwater at concentrations in excess of 25,000 ppb suggests that non-aqueous phase liquids are present as well, particularly in the residual form. For example, trichloroethene was detected at a concentration of 25,000 ppb in monitoring well 744-0115 and has subsequently been confirmed by duplicate analysis. This well is screened at the base of the Lower Cohansey water-bearing zone at an elevation of approximately 40 feet below mean sea level. Moreover, this well is situated in a groundwater discharge area, wherein groundwater flow paths have a significant component of vertically upward flow. The presence of such elevated concentrations (2.5 percent of pure product) observed at the base of the unit, in a discharge area, and beneath the semi-confining layer of the Cohansey/Kirkwood Transitional Unit suggests that migration is, at least in part, density-determined. Moreover, it is statistically unlikely that this particular well encountered the point of maximum concentration in this area.

Evidence for the existence of pooled, non-aqueous phase liquids includes the results of HNU analyses of soil samples from numerous soil borings (see Table 4-1). The HNU data indicate a generally consistent pattern of highest response at or slightly above the interface of a lower permeability layer. The distribution of contaminants at the base of the water-bearing zone suggests the occurrence of density-determined flow, since downward vertical hydraulic gradients are quite small or are non-existent. The distribution pattern, by definition, implies the presence of pooled, non-aqueous phase liquids in the structurally lowest points in the system.

In consideration of the mechanisms of non-aqueous phase liquid migration, the history of industrial site use, and the technical evidence described above, the conclusion that non-aqueous phase liquids are present beneath the site, both as a residual and in pooled form, is inescapable.

3.4 Waste Component Characteristics

Table 3-5 lists the characteristics of selected organic compounds observed in the groundwater at the Toms River Plant. The table includes data regarding the molecular weight, specific gravity, solubility, viscosity, and vapor pressure for the selected compounds. Where data is available, we have also included the octanol/water partition coefficients (K_{ow}). Common synonyms are also provided.

TABLE 3-5

CHARACTERISTICS OF SELECTED ORGANIC COMPOUNDS

Compound	CAS Number	Synonyms	Formula	Molecular Weight	Specific Gravity	Vapor* Pressure	Solubility,%	K_{ow}	Viscosity**
Volatile Organics									
Benzene	71-43-2	benzol	C_6H_6	78.1	0.879	74.6	0.06	1.95-2.13	0.6028
Chlorobenzene	108-90-7	monochlorobenzene	C_6H_5Cl	112.6	1.11	11.8	0.049	2.83	0.799
Chloroform	67-66-3	trichloromethane	$CHCl_3$	119.4	1.489	1.59	0.8	1.97	0.596
Ethyl Benzene	100-41-4	phenylethene	C_8H_{10}	106.1	0.867	10	0.015	3.15	0.678
Trichloroethene	79-01-6	trichloroethylene	C_2HCl_3	131.4	1.46	58	0.1	2.29	0.565
Tetrachloroethene	127-18-4	tetrachloroethylene per chloroethylene	C_2Cl_4	165.8	1.623	15.8	150-200 mg/l	2.88	ND
1,1,1-Trichloroethane	71-55-6	methychloroform	$C_2H_3Cl_3$	133.4	1.3(31)	100	0.09	2.17	0.903
1,2-Dichloroethane	107-06-2	ethylene dichloride	$C_2H_4Cl_2$	99.0	1.257	87	8690 mg/l	1.48	0.887
Trans-1,2-Dichloroethene	156-60-5	trans 1,2 dichloroethylene	$C_2H_2Cl_2$	96.9	1.26	200	600 mg/l	1.48	0.404
Toluene	100-88-3	methylbenzene	C_7H_8	92.1	0.866	28	0.05	2.69	0.587
Trichloropropane (1,2,3)	96-18-4	allyltrichloride	$CH_2ClCHClCH_2Cl$	147.44	1.417	2	ND	ND	ND
Base/Neutral Extractable Organics									
1,2-Dichlorobenzene	95-50-1	orthodichlorobenzene	$C_6H_4Cl_2$	147.0	1.3	1.2	0.015	3.38	1.324
Nitrobenzene	98-95-3	nitrobenzol	$C_6H_5NO_2$	123.1	1.2	4.25	1900 mg/l	1.85	1.634
Naphthalene	91-20-3	napahol	$C_{10}H_8$	128.2	1.145	0.0492 ton	3.17-34.4 mg/l	3.37	0.780 (at 100°C)

* = mm, Hg
** = in centipoises at 20°C
ND = No data

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4.0 HYDROGEOLOGIC INVESTIGATION

4.1 Methods and Procedures

The field investigations described in this section consisted of the drilling of a total of 59 test borings and the installation of 102 monitoring wells. The borings and monitoring wells were intended to supplement the previously existing hydrogeologic database that consisted of 84 monitoring wells, 32 small diameter piezometers, and more than 150 test borings. In addition, geologic logs for borings and/or production wells of the Toms River Water Company are available and have been used in the analysis of stratigraphic conditions in the region of concern.

The currently available hydrogeologic database thus consists of 186 monitoring wells and 32 piezometers. Geologic data is available from more than 150 discrete locations. Detailed logs of the borings and monitoring well installations performed for this investigation are provided in Volume II of this document. Logs of borings, monitoring wells, and piezometers performed during previous subsurface investigations are provided in Volume III. Logs of borings and wells of the Toms River Water Company are also included in Volume III.

The investigations described in this section can be subdivided into two general categories as follows:

1. The USEPA Remedial Investigation performed by the NUS Corporation;

2. Supplemental investigations performed by AWARE, Incorporated on behalf of Ciba-Geigy.

The specific methods and prodedures of these investigations are described below.

4.1.1 The USEPA/NUS Remedial Investigation

The comprehensive field program conducted by the NUS Corporation on behalf of USEPA consisted of a multi-media sampling effort designed to address the potential for contamination in groundwater, surface water, shallow soils, and stream sediment. The investigative program included the use of surface and borehole geophysical techniques, the drilling of test borings and the installation of monitoring wells, and the collection of soil, groundwater, surface water, and stream sediment samples for laboratory analysis. The sampling programs for each of these media are briefly summarized below.

Test Borings and Monitoring Wells

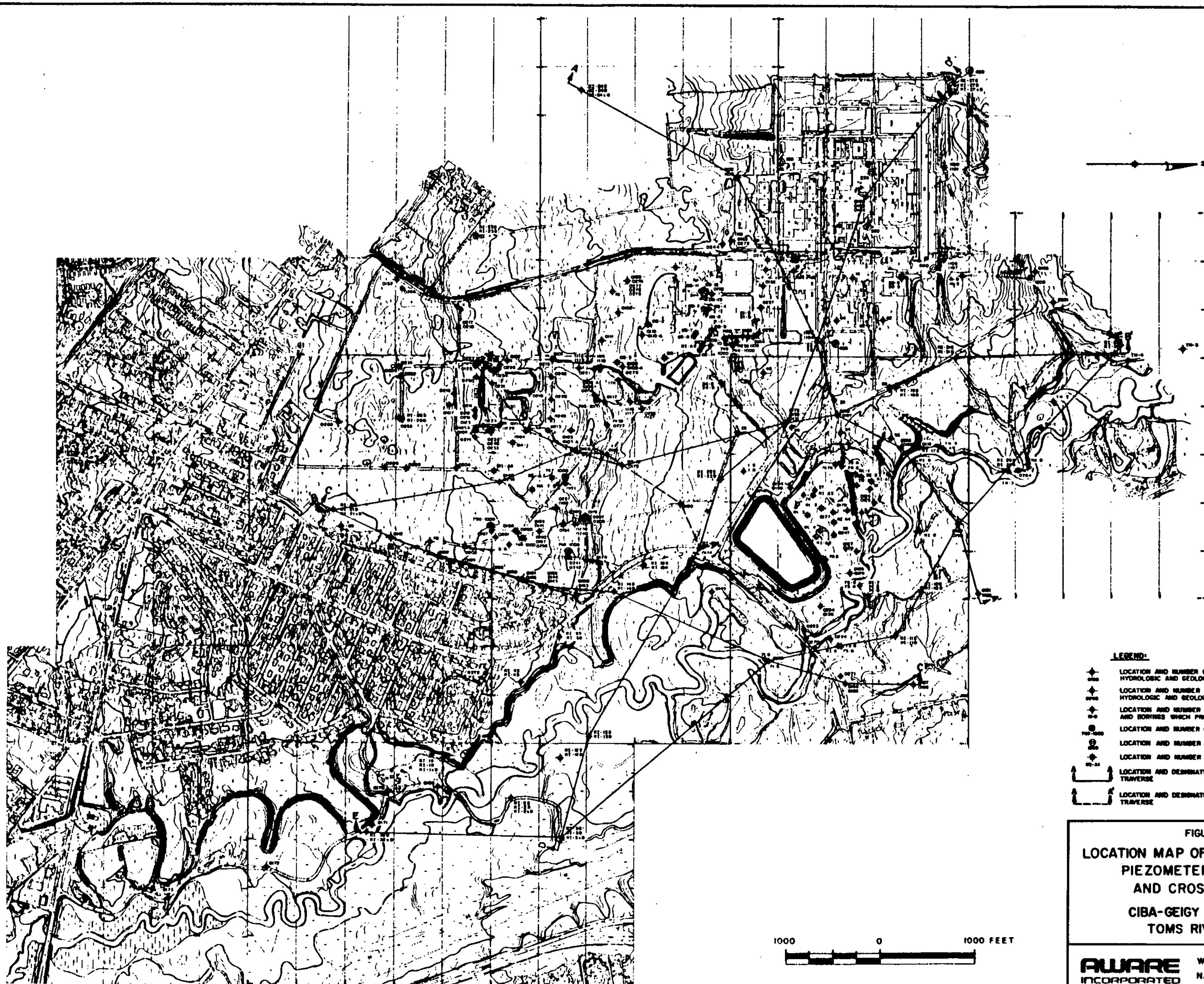
An extensive investigation consisting of the drilling of 32 test borings, the installation of 61 monitoring wells, and the drilling of 8 shallow auger borings was performed under the direction of the NUS Corporation. Field geologists from AWARE observed the NUS drilling program as representatives of Ciba-Geigy. The test borings were located primarily along the perimeter of the Toms River Plant site, at a limited number of interior, on-site locations, and in the off-site areas adjacent to the Toms River. The monitoring wells installed by NUS are designated as RI-1 through RI-32. Their locations are indicated on Figure 4-1. A larger scale (1 inch = 400 feet) reproduction of Figure 4-1 has also been included in the map pocket at the rear of this volume.

The test borings performed by NUS were conducted using several different drilling methods. The borings for wells RI-1 through RI-5, for example, were drilled solely with the use of hollow stem augers. Due to the nature of the soils and the frequency of borehole collapse, the drilling method was subsequently modified to combine hollow stem augering and the mud rotary method. Hollow stem augers were generally used to advance the borehole to the water table. Mud rotary methods were primarily used when drilling below the water table was required. The majority of the monitoring wells were thus achieved via the latter method. Drilling services were provided by Hardin-Huber Associates of Pasadena, Maryland and W. C. Services (formerly Schultes) of Woodbury, New Jersey.

A selective soil sampling program was employed by NUS during the drilling of the test borings. The selective sampling program consisted of the collection of split-spoon samples from each boring at intervals determined by the NUS on-site geologist. The program typically focused upon the identification of a geologic "marker" horizon (the black organic sand) usually found at considerable depth within the Cohansey Formation and upon locating the presumed contact between the Cohansey Formation and the underlying Kirkwood Formation. Stratigraphic units above the marker horizon were typically not sampled, while stratigraphic units between the marker horizon and the Cohansey/Kirkwood contact were only occasionally sampled. The actual intervals sampled are indicated on the test boring logs included in Volume II of this document.

Upon the retrieval of each split-spoon sample, the NUS field geologist visually classified the soils and selected a representative portion for future reference. The remaining contents of the split-spoon were then made available to the AWARE field geologist. The AWARE geologist visually classified the soils using a classification system modified after Burmister (1958), and also selected a representative portion from the split-spoon sampler. The sample was then placed in an eight-ounce glass jar, sealed with aluminum foil and the jar lid, and allowed to equilibrate approximately to room temperature. Upon sufficient equilibration, an HNU Systems model PI-101 Photoionization Analyzer was used to sample the head space of the sample jar for the presence of volatile organic trace gases. The occurrence of an "HNU anomaly" was presumed to indicate the potential presence in the sample of volatile organic contamination. All results of the AWARE field HNU analyses were made available to NUS during the field investigation and are summarized on Table 4-1.

The monitoring wells installed by NUS were constructed of four-inch diameter, threaded, flush-joint steel casing with a 20-slot Johnson Co. stainless steel screen. A screen length of ten feet was typically employed, although six-foot lengths of screen were used on a number of installations. The monitoring wells completed at the base of the Cohansey Formation were typically completed with a three-foot section of steel casing below the screen. This "cellar" enabled placement of a natural gamma geophysical probe at a sufficient depth in the well to record the gamma signature of the stratigraphic contact.



LEGEND:

- LOCATION AND NUMBER OF MONITORING WELLS WHICH PROVIDE HYDROLOGIC AND GEOLOGIC INFORMATION
- LOCATION AND NUMBER OF PIEZOMETERS WHICH PROVIDE HYDROLOGIC AND GEOLOGIC INFORMATION
- LOCATION AND NUMBER OF MONITORING WELLS, PIEZOMETERS, AND BORINGS WHICH PROVIDE ONLY GEOLOGIC INFORMATION
- LOCATION AND NUMBER OF PURGE WELLS
- LOCATION AND NUMBER OF PRODUCTION WELLS
- LOCATION AND NUMBER OF AUGER BORINGS
- LOCATION AND DESIGNATION OF GEOLOGIC CROSS SECTION TRAVERSE
- LOCATION AND DESIGNATION OF GEOPHYSICAL CROSS SECTION TRAVERSE

FIGURE 4-1

LOCATION MAP OF MONITORING WELLS, PIEZOMETERS, BORINGS, AND CROSS-SECTIONS

CIBA-GEIGY CORPORATION TOMS RIVER PLANT

AWARE INCORPORATED — WEST MILFORD, NEW JERSEY; NASHVILLE, TENNESSEE

TABLE 4-1

SUMMARY OF FIELD HNU ANALYSES

Boring Number	Sample Number	Sample Depth	Geologic Unit	HNU Value (in ppm)
RI-1	S-1	5-6.5	Cohansey	NA
	S-2	10-11.5	Cohansey	NA
	S-3	15-16.5	Cohansey	0.2
	S-4	20-21.5	Cohansey	0.3
	S-5	25-26.5	Cohansey	0.8
	S-6	30-31.5	Cohansey	0.8
	S-7	35-36.5	Coh/Kw	0.3
	S-8	36.5-38	Coh/Kw	0.2
	S-9	38-39.5	Coh/Kw	0.1
RI-2	S-1	4.5-6	Cohansey	NA
	S-2	9.5-11	Cohansey	NA
	S-3	14.5-16	Cohansey	NA
	S-4	17.5-19	Cohansey	NA
RI-3	S-1	3-4.5	Cohansey	ND
	S-2	8-9.5	Cohansey	ND
	S-3	13-14.5	Cohansey	ND
	S-4	14.5-16	Cohansey	ND
	S-5	16.5-18	Cohansey	0.3
	S-6	18.5-20	Cohansey	1.9
RI-4	S-1	43-45	Cohansey	0.6
	S-2	48-50	Cohansey	8.8
	S-3	53-55	Cohansey	1.2
	S-4	58-60	Cohansey	2.0
	S-5	63-65	Cohansey	3.2
	S-6	68-70	Cohansey	0.2
	S-7	70-72	Cohansey	3.9
	S-8	72-74	Cohansey	0.7
	S-9	74-76	Cohansey	19.4
	S-10	76-78	No Recovery	NA
	S-11	78-80	Coh/Kw	10.0
	S-12	80-82	Coh/Kw	NA
	S-13	82-84	Coh/Kw	NA

TABLE 4-1, continued

SUMMARY OF FIELD HNU ANALYSES

Boring Number	Sample Number	Sample Depth	Geologic Unit	HNU Value (in ppm)
RI-5	S-1	28.5-30	Cohansey	0.4
	S-2	33.5-35	Cohansey	0.2
	S-3	38.5-40	Cohansey	ND
	S-4	43.5-45	Cohansey	3.3
	S-5	48.5-50	Cohansey	0.3
	S-6	53.5-55	Cohansey	0.8
	S-7	58.5-60	Cohansey	0.9
	S-8	60.5-62	Cohansey	1.5
	S-9	62-64	Cohansey	2.6
	S-10	64-66	Coh/Kw	5.5
	S-11	66-68	Coh/Kw	6.4
	S-12	68-70	Coh/Kw	2.0
RI-6	S-1	5-7	Cohansey	0.2
	S-2	10-12	Cohansey	0.2
	S-3	15-17	Cohansey	ND
	S-4	20-22	Cohansey	0.1
	S-5	22-24	Cohansey	ND
	S-6	24-26	Cohansey	ND
	S-7	26-28	Cohansey	ND
	S-8	28-30	Cohansey	0.01
	S-9	30-32	Cohansey	ND
	S-10	32-34	Cohansey	ND
	S-11	34-36	Coh/Kw	ND
	S-12	36-38	Coh/Kw	ND
RI-7	S-2	2-4	Cohansey	ND
	S-3	7-9	Cohansey	ND
	S-4	12-14	Cohansey	ND
	S-5	17-19	Cohansey	0.1
	S-6	19-21	Cohansey	ND
	S-7	21-23	Cohansey	0.1
	S-8	23-25	Cohansey	ND
	S-9	25-27	Cohansey	ND
	S-10	27-29	Coh/Kw	0.1
	S-11	29-31	Coh/Kw	ND
	S-12	31-33	Coh/Kw	ND
	S-13	33-35	Coh/Kw	0.2
RI-8	S-1	5-7	Cohansey	0.4
	S-2	10-12	Cohansey	0.2
	S-3	15-17	Cohansey	0.1
	S-4	20-22	Cohansey	0.2
	S-5	25-27	Cohansey	0.3
	S-6	27-29	No Recovery	NA
	S-7	29-31	Cohansey	0.3
	S-8	31-33	Cohansey	0.2
	S-9	33-35	Coh/Kw	0.1

TABLE 4-1, continued

SUMMARY OF FIELD HNU ANALYSES

Boring Number	Sample Number	Sample Depth	Geologic Unit	HNU Value (in ppm)
	S-10	35-37	Coh/Kw	0.2
	S-11	37-39	Coh/Kw	0.1
	S-12	39-41	Coh/Kw	0.1
	S-13	41-43	Coh/Kw	0.2
	S-14	43-45	Coh/Kw	0.1
RI-9	S-1	2-4	Cohansey	0.2
	S-2	7-9	Cohansey	0.2
	S-3	12-14	Cohansey	0.3
	S-4	17-19	Cohansey	8.0
	S-5	22-24	Coh/Kw	22.0
	S-6	24-26	Coh/Kw	6.5
	S-7	26-28	Coh/Kw	3.4
	S-8	28-30	Coh/Kw	2.0
RI-10	S-2	5-7	Cohansey	0.1
	S-3	10-12	Cohansey	0.1
	S-4	15-17	Cohansey	ND
	S-5	20-22	Cohansey	0.1
	S-6	22-24	Cohansey	0.1
	S-7	24-26	Cohansey	0.2
	S-8	26-28	Cohansey	0.1
	S-9	28-30	Cohansey	0.2
	S-10	30-32	Cohansey	0.2
	S-11	32-34	Cohansey	0.1
	S-12	34-36	Coh/Kw	0.2
	S-13	36-38	Coh/Kw	0.1
RI-22	S-1	70-72	Coh/Kw	3.0
	S-2	72-74	Coh/Kw	3.5
744-0176	S-1	15-17	Cohansey	21.0
	S-2	20-22	Cohansey	9.0
	S-3	25-27	Cohansey	14.0
	S-4	30-32	Cohansey	3.5
	S-5	37-39	Coh/Kw	11.0
	S-6	39-41	Coh/Kw	16.0
	S-7	41-43	Coh/Kw	12.0
744-0177	S-1	8-10	Fill/Cohansey	17.0
	S-2	13-15	Fill/Cohansey	1.5
	S-3	18-20	Fill/Cohansey	3.0
	S-4	23-25	Fill/Cohansey	4.0
	S-5	28-30	Coh/Kw	14.0
	S-6	33-35	Coh/Kw	22.0
	S-7	35-37	Coh/Kw	14.5
	S-8	37-39	Coh/Kw	18.0

TABLE 4-1, continued

SUMMARY OF FIELD HNU ANALYSES

Boring Number	Sample Number	Sample Depth	Geologic Unit	HNU Value (in ppm)
744-0178	S-1	10-12	Cohansey	5.0
	S-2	15-17	Cohansey	7.3
	S-3	20-22	Cohansey	13.0
	S-4	25-27	Cohansey	7.0
	S-5	30-32	Coh/Kw	19.0
	S-6	32-34	Coh/Kw	1.5
	S-7	34-36	Coh/Kw	2.5
744-0179	S-14	26-28	Cohansey	ND
	S-15	28-30	Cohansey	1.2
	S-16	30-32	Cohansey	0.7
	S-17	32-34	Cohansey	0.85
	S-18	34-36	Cohansey	<1
	S-24	46-48	Cohansey	<1
	S-25	48-50	Cohansey	1.6
	S-26	50-52	Cohansey	<1
	S-31	60-62	Cohansey	<1
	S-32	62-64	Cohansey	2.5
	S-33	64-66	Cohansey	4
	S-34	66-68	Cohansey	34
	S-35	68-70	Cohansey	4.6
	S-36	70-72	Cohansey	40
	S-37	72-74	Cohansey	42
	S-38	74-76	Coh/Kw	70
	S-39	76-78	Coh/Kw	32
	S-40	78-80	Coh/Kw	6
	S-41	80-82	Coh/Kw	3.2
	S-42	82-84	Coh/Kw	1.6
	S-43	90-92	Coh/Kw	<1
	S-44	95-97	Lower Cohansey	<1
	S-45	97-99	Lower Cohansey	1.6
	S-46	99-101	Lower Cohansey	<1
	S-51	117-119	Upper Kirkwood	<1
	S-52	122-124	Upper Kirkwood	1.2
	S-53	130-132	Upper Kirkwood	<1
	S-77	250-251.5	Shark River/Manasquan	<1
744-0180	S-1	0-2	Primary Cohansey	<1
			All HNU readings are Less than 1 ppm	
	S-62	190-192	Shark River Manasquan	<1
744-0181	S-1	3-5	Upper Cohansey	<1
	S-21	43-45	Primary Cohansey	<1
	S-22	45-47	Primary Cohansey	5.0
	S-23	47-49	Primary Cohansey	4.0
	S-24	49-51	Primary Cohansey	10.0
	S-25	51-53	Primary Cohansey	4.0

TABLE 4-1, continued

SUMMARY OF FIELD HNU ANALYSES

Boring Number	Sample Number	Sample Depth	Geologic Unit	HNU Value (in ppm)
	S-26	53-55	Primary Cohansey	17.0
	S-27	55-57	Primary Cohansey/ Black Organic Sand	25.0
	S-28A	57-59	Black Organic Sand	.10
	S-28B	59-61	Primary Cohansey	7.0
	S—29	61-63	Primary Cohansey	<1
	S-32	67-69	Primary Cohansey	2.0
	S-33	69-71	Primary Cohansey	3.5
	S-34	71-73	Primary Cohansey	<1
	S-35	76-78	Contact Coh/KW Trans	60
	S-36	78-80	Contact Coh/KW Trans	42
	S-37	83-85	Contact Coh/KW Trans	<1
	S-43	110-111.5	Upper Kirkwood	<1
	S-44A/44B	115-116.5	Upper Kirkwood	2.5/1.0
	S-45	120-121.5	Upper Kirkwood	1.5
	S-46	125-126.5	Upper Kirkwood	.5
	S-47	130-136.5	KW #1 Sand	1.5
	S-48	135-136.5	KW #1 Sand	<2
	S-65	223-224.5	KKW #1 Sand	<2
744-0182	S-1	5-7	Upper Cohansey	<1
	S-17	49-51	Primary Cohansey	1.1
	S-18	51-53	Primary Cohansey	<1
	S-28	71-73	Coh/KW Trans Unit	<1
	S-29	75-77	Coh/KW Trans Unit	5
	SH-30	77-79	Coh/KW Trans Unit	20
	S-30	80-82	Coh/KW Trans Unit	20
	S-31A	82-84	Lower Cohansey	8.0
	S-31B		Lower Cohansey	1.0
	S-32	84-86	Lower Cohansey	<1
	S-61	222.5-224	Shark River/Manasquan	<1
744-0185 744-0187 744-0189 744-0191	All Winding River Park Drilling Locations Show Non-detectable HNU Readings			
744-0194	S-1	5-7	Upper Cohansey	<1
	S-20	46-48	Primary Cohansey	<1
	S-21	51-53	Primary Cohansey	62
	S-22	56-58	Primary Cohansey	98
	S-23	60-62	Coh/KW Trans Unit	6
	S-24	62-64	Coh/KW Trans Unit	<1
	S-38	98-100	Upper Kirkwood	<1
744-0196	S-1	5-7	Primary Cohansey	18
	S-3	10-12	Primary Cohansey	60
	S-3	15-17	Primary Cohansey	<1

TABLE 4-1, continued

SUMMARY OF FIELD HNU ANALYSES

Boring Number	Sample Number	Sample Depth	Geologic Unit	HNU Value (in ppm)
	S-10	41-43	Primary Cohansey	<1
	S-11	45-47	Primary Cohansey	9.4
	S-12	49-51	Primary Cohansey	3.2
	S-13	53-55	Primary Cohansey BOS	6.4
	S-14	55-57	Primary Cohansey BOS	42
	S-15	57-59	Primary Cohansey BOS	12
	S-16	59-61	Contact Coh w/Coh/KW	6.2
	S-17	63-65	Coh/KW Trans Unit	10
	S-18	65-67	Coh/KW Trans Unit	1.0
	S-26	87-89	Lower Cohansey	<1
	S-27	91-93	Lower Cohansey	7.0
	S-28	93-95	Upper Kirkwood	1.0
	S-29	95-997	Upper Kirkwood	<1
	S-30	100-102	Upper Kirkwood	<1
744-0198	S-1	5--7	Primary Cohansey	7.0
	S-2	10-12	Primary Cohansey	10
	S-3	15-17	Primary Cohansey	8
	S-4	20-22	Primary Cohansey	<1
	S-10	46-48	Primary Cohansey	<1
	S-11	48-50	Coh/KW Trans Unit	1.2
	S-12	52-54	Coh/KW Trans Unit	5.0
	S-13	54-56	Coh/KW Trans Unit	4.2
	S-14	56-58	Coh/KW Trans Unit	4.0
	S-15	58-60	Coh/KW Trans Unit	7.0
	S-16	60-62	Coh/KW Trans Unit	7.0
	S-17	65-67	Lower Cohansey	17.0
	S-18	67-69	Lower Cohansey	9.0
	S-19	69-71	Lower Cohansey	2.0
	S-20	74-76	Lower Cohansey	1.2
	S-21	78-80	Lower Cohansey	2.0
	S-22	80-82	Lower Cohansey	<1
	S-29	97-99	Upper Kirkwood	<1
744-1100	S-1	5-7	Primary Cohansey	<1
	S-26	115-117	Upper Kirkwood	<1
744-1102	S-1	5-7	Upper Cohansey	<1
	S-28	110-112	Upper Kirkwood	<1
744-1104	S-1	5-7	Upper Cohansey	<1
	S-13	65-67	Primary Cohansey	<1
	S-14	70-72	Cont PrCoh/KWTrans	2.0
	S-15	72-74	Coh/KW Trans Unit	1.4
	S-16	74-76	Coh/KW Trans Unit	9.4
	S-17	76-78	Coh/KW Trans Unit	21.4
	S-18	78-80	Coh/KW Trans Unit	42
	S-19	80-82	Coh/KW Trans Unit	40.0

TABLE 4-1, continued

SUMMARY OF FIELD HNU ANALYSES

Boring Number	Sample Number	Sample Depth	Geologic Unit	HNU Value (in ppm)
	S-20	82-84	Coh/KW Trans Unit	38.0
	S-21	84-86	Coh/KW Trans Unit	36.0
	S-22	86-88	Coh/KW Trans Unit	10
	S-23	90-92	Lower Cohansey	3.0
	S-24	95-97	Lower Cohansey	4.2
	S-25	100-102	Lower Cohansey	3.6
	S-26	105-107	Lower Cohansey	7.4
	S-27	110-112	Upper Cohansey	<1
	S-28	115-117	Upper Cohansey	<1
744-1106	S-1	5-7	Primary Cohansey	<1
	S-23	110-112	Upper Kirkwood	<1
744-1108	S-1	5-7	Upper Cohansey	22
	S-2	10-12	Upper Cohansey	24
	S-3	13-15	Primary Cohansey	22
	S-4	18-20	Primary Cohansey	18-12
	S-5	23-25	Primary Cohansey	15/12
	S-6	28-30	Primary Cohansey	12
	S-7	33-35	Primary Cohansey	53
	S-8	38-40	Primary Cohansey	50
	S-9	43-45	Primary Cohansey	NA
	S-10	45-47	Primary Cohansey	40
	S-11	50-52	Primary Cohansey	<1
	S-12	55-57	Primary Cohansey	<1
	S-13	60-62	Primary Cohansey	30/10
	S-14	63-65	Coh/KW Trans Unit	50/20
	S-15	70-72	Coh/KW Trans Unit	12/6
	S-16	75-77	Coh/KW Trans Unit	15/7
	S-17	80-82	Coh/KW Trans Unit	<1
	S-18	85-87	Coh/KW Trans Unit	<1
	S-19	90-92	Lower Cohansey	1.0
	S-20	95-97	Contact Upper KW	<1
	S-27	135-137	KW No. 1 Sand	<1
744-1109	S-1	5-7	Upper Cohnsey	<1
	S-8	40-42	Primary Cohansey	28
	S-9	45-47	Primary Cohansey	1.2
	S-10	50-52	Primary Cohansey	1.2
	S-11	55-57	Primary Cohansey	3.5
	S-12	60-62	Primary Cohansey	22
	S-13	65-67	Cont PrCo/KWTrans	60/50
	S-L4	67-69	Coh/KW Trans Unit	130/100
	S-15	70-72	Coh/KW Trans Unit	75
	S-16	75-77	Coh/KW Trans Unit	11
	S-17	80-82	Coh/KW Trans Unit	<1
	S-18	85-87	Coh/KW Trans Unit	1.4
	S-19	90-92	Lower Cohansey	5.5

TABLE 4-1, continued

SUMMARY OF FIELD HNU ANALYSES

Boring Number	Sample Number	Sample Depth	Geologic Unit	HNU Value (in ppm)
	S-20	95-96	Lower Cohansey	3.2
	S-21	100-102	Upper Cohansey	<1
	S-29	140-142	KW No. 1 Sand	<1
744-1110	S-1	5-7	Upper Cohansey	<1
	S-8	40-42	Primary Cohansey	1.7
	S-29	148-150	KW No. 1 Sand	1
744-1111	S-1	5-7	Upper Cohansey	<1
	S-2	10-12	Coh "Yellow" Clay	3.9
	S-3	12-14	Coh "Yellow" Clay	200/90
	S-4	16-18	Coh "Yellow" Clay	17/10
	S-5	18-20	Primary Cohansey	2.2
	S-6	21-23	Primary Cohansey	5/3.6
	S-7	23-25	Primary Cohansey	10/5
	S-8	25-27	Primary Cohansey	4.5
	S-9	27-29	Primary Cohansey	2.5
	S-10	32-34	Primary Cohansey	2.2
	S-11	34-36	Primary Cohansey	2.0
	S-12	38-40	Primary Cohansey	2
	S-12A	40-42	Primary Cohansey	3
	S-13	43-45	Primary Cohansey	1
	S-14	45-47	Primary Cohansey	5
	S-15	47-49	Primary Cohansey	2.2
	S-16	49-51	Primary Cohansey	1.2
	S-17	51-52	Primary Cohansey	<1
	S-20	56-58	Primary Cohansey	<1
	S-21	58-60	Primary Cohansey	25
	S-22	60-62	Coh/KW Trans Unit	1.8
	S-23	62-64	Coh/KW Trans Unit	1.3
	S-24	64-66	Coh/KW Trans Unit	<1
	S-25	66-68	Coh/KW Trans Unit	25.2
	S-26	68-70	Coh/KW Trans Unit	2.0
	S-27	75-77	Coh/KW Trans Unit	1.8
	S-28	80-82	Coh/KW Trans Unit	ND
	S-32	100-102	Upper Kirkwood	ND
744-1112	S-1	4-66	Upper Kirkwood	2.1
	S-2	10-12	Upper Kirkwood	6/2
	S-3	12-14	Upper Kirkwood	9.5/2.3
	S-4	14-16	Upper Kirkwood	<1
	S-5	16-18	Coh "Yellow" Clay	1.1
	S-6	18-20	Coh "Yellow" Clay	1.1
	S-7	20-22	Coh "Yellow" Clay	5.4
	S-8	22-24	Coh "Yellow" Clay	20/2.8
	S-9	24-26	Primary Cohansey	50/5
	S-10	26-28	Primary Cohansey	25/3.2
	S-11	28-30	Primary Cohansey	3.8/3
	S-12	30-32	Primary Cohansey	2.2

TABLE 4-1, continued

SUMMARY OF FIELD HNU ANALYSES

Boring Number	Sample Number	Sample Depth	Geologic Unit	HNU Value (in ppm)
	S-13	32-34	Primary Cohansey	2
	S-14	34-36	Primary Cohansey	5
	S-15	36-38	Primary Cohansey	4
	S-16	38-40	Primary Cohansey	.6
	S-17	40-42	Primary Cohansey	9
	S-18	42-44	Primary Cohansey	1.8
	S-19	44-46	Primary Cohansey	1
	S-20	46-48	Primary Cohansey	<1
	S-21	48-50	Primary Cohansey	2
	S-22	50-52	Primary Cohansey	20
	S-23	52-54	Primary Cohansey	2
	S-24	54-56	Primary Cohansey	<1
	S-25	56-58	Primary Cohansey	<1
	S-26	58-60	Primary Cohansey	3.2
	S-27	60-62	Primary Cohansey	<1
	S-34	74-76	Coh/KW Trans Unit	<1
	S-35	76-78	Coh/KW Trans Unit	5.2/1.7
	S-36	78-80	Coh/KW Trans Unit	<1
	S-37	80-82	Coh/KW Trans Unit	<1
	S-38	82-84	Coh/KW Trans Unit	3.8/2
	S-39	84-86	Coh/KW Trans Unit	<1
	S-43	92-94	Lower Cohansey	<1
744-1114	S-1	4-6	Upper Cohansey	<1
	S-2	10-12	Upper Cohansey	ND
	S-3	12-14	Upper Cohansey	45
	S-4	14-16	Upper Cohansey	20/10
	S-5	16-18	Coh "Yellow" Clay	72/50
	S-6	18-20	Coh "Yellow" Clay	110/70
	S-7 A,B,C	20-22	Coh "Yellow"Clay	200,100,260
	S-8 A,B,C	22-24	Coh"Yellow"Clay	200,80/40,42/30
	S-9 A,B	24-26	Coh "Yellow" Clay	3.8,2.8
	S-10	26-28	Primary Cohansey	1.8/1
	S-11	28-30	Primary Cohansey	25
	S-12	30-32	Primary Cohansey	8.4
	S-13	32-34	Primary Cohansey	3.2
	S-14	34-36	Primary Cohansey	1.2
	S-15	36-38	Primary Cohansey	2.8
	S-16	38-40	Primary Cohansey	1.0
	S-17	40-42	Primary Cohansey	4/.2
	S-18	42-44	Primary Cohansey	1.2
	S-19 A,B	44-46	Primary Cohansey	<1,<1
	S-20	46-48	Primary Cohansey	8
	S-21	48-50	Primary Cohansey	4.2
	S-22	50-52	Primary Cohansey	4.4
	S-23	52-54	Primary Cohansey	<1
	S-28	62-64	Primary Cohansey	1.2
	S-29	64-66	Primary Cohansey	<1

TABLE 4-1, continued

SUMMARY OF FIELD HNU ANALYSES

Boring Number	Sample Number	Sample Depth	Geologic Unit	HNU Value (in ppm)
	S-33	72-74	Coh/KW Trans Unit	<1
744-1116	S-1	5-7	Upper Cohansey	ND
	S-11	26-28	Primary Cohansey	<1
	S-12	28-30	Primary Cohansey	NA
	S-13	30-32	Primary Cohansey	28/10
	S-14	32-34	Primary Cohansey	30/10
	S-15	34-36	Primary Cohansey	58/30
	S-16	36-38	Primary Cohansey	70/40
	S-17	38-40	Primary Cohansey	8/5
	S-18	40-42	Primary Cohansey	7.2/2.4
	S-19	42-44	Primary Cohansey	<1
	S-20	44-46	Primary Cohansey	10.8/5
	S-21	46-48	Primary Cohansey	22/18
	S-22	48-50	Primary Cohansey	13.5/9.8
	S-23	50-52	Primary Cohansey	14.6/8
	S-24	52-54	Primary Cohansey	77/4
	S-25	54-56	Coh/KW Trans Unit	6/2
	S-26	56-58	Coh/KW Trans Unit	6/1.8
	S-27	58-60	Coh/KW Trans Unit	6.4/1.6
	S-28	60-62	Coh/KW Trans Unit	5.2
	S-29	62-64	Coh/KW Trans Unit	2.2
	S-32	70-72	Coh/KW Trans Unit	<1

ND indicates meter response not detected
NA indicates no reading taken

Monitoring well couplets were installed at sixteen of the thirty-two test boring locations. Monitoring well triplets were constructed at seven locations. At five of the seven triplet locations, deep exploratory borings were performed. In order to minimize the potential for cross-contamination of deeper water-bearing zones, the deep borings were conducted using the double-cased method. Single well installations were performed adjacent to existing monitoring wells at eight locations. Figures 4-2 through 4-4 illustrate the methods of construction for a typical monitoring well. Specific details of the monitoring well construction are provided on the test boring logs in Volume II of this document.

Auger Borings

In order to characterize the nature and extent of waste disposal, shallow auger borings were performed at three of the suspected source areas. The areas investigated were as follows:

1. The Former River Lagoon Area

2. The Former Sludge Disposal Area

3. The Treatment Plant Area

The auger borings are designated as RI-A-1 through RI-A-8. Borings RI-A-1 through RI-A-5 are located in the Former River Lagoon Area; borings RI-A-6 and RI-A-7 are located in the Former Sludge Disposal Area; boring RI-A-8 is located in the Treatment Plant Area. The auger boring locations are indicated on Figure 4-1.

Drilling services were provided by W.C. Services of Woodbury, New Jersey using a truck-mounted drill rig equipped with hollow stem augers. The drilling was performed under the direct supervision of NUS and was observed by AWARE. Split-spoon samples were obtained from each boring at two-foot intervals unless otherwise specified by NUS. Representative samples from each split-spoon were visually classified in the field and retained for future reference by both NUS and AWARE.

AWARE again used the HNU Photoionization Analyzer to screen the samples for the presence of volatile organic trace gases. The results of the sample screening are summarized on Table 4-2.

Thirty-two of the samples obtained from the auger boring program were submitted by NUS for analysis by the EPA contract laboratory. Four samples from each of the eight auger borings were analyzed for the priority pollutants + 40. In addition, single samples from each of the eight borings were tested for dioxin. The analytical reports are reproduced in Volume V.

The analyses suggest that sludges and/or backfill soils in the Former River Lagoon Area, the Former Sludge Disposal Area, and the Treatment Plant Area, may contain the following compounds:

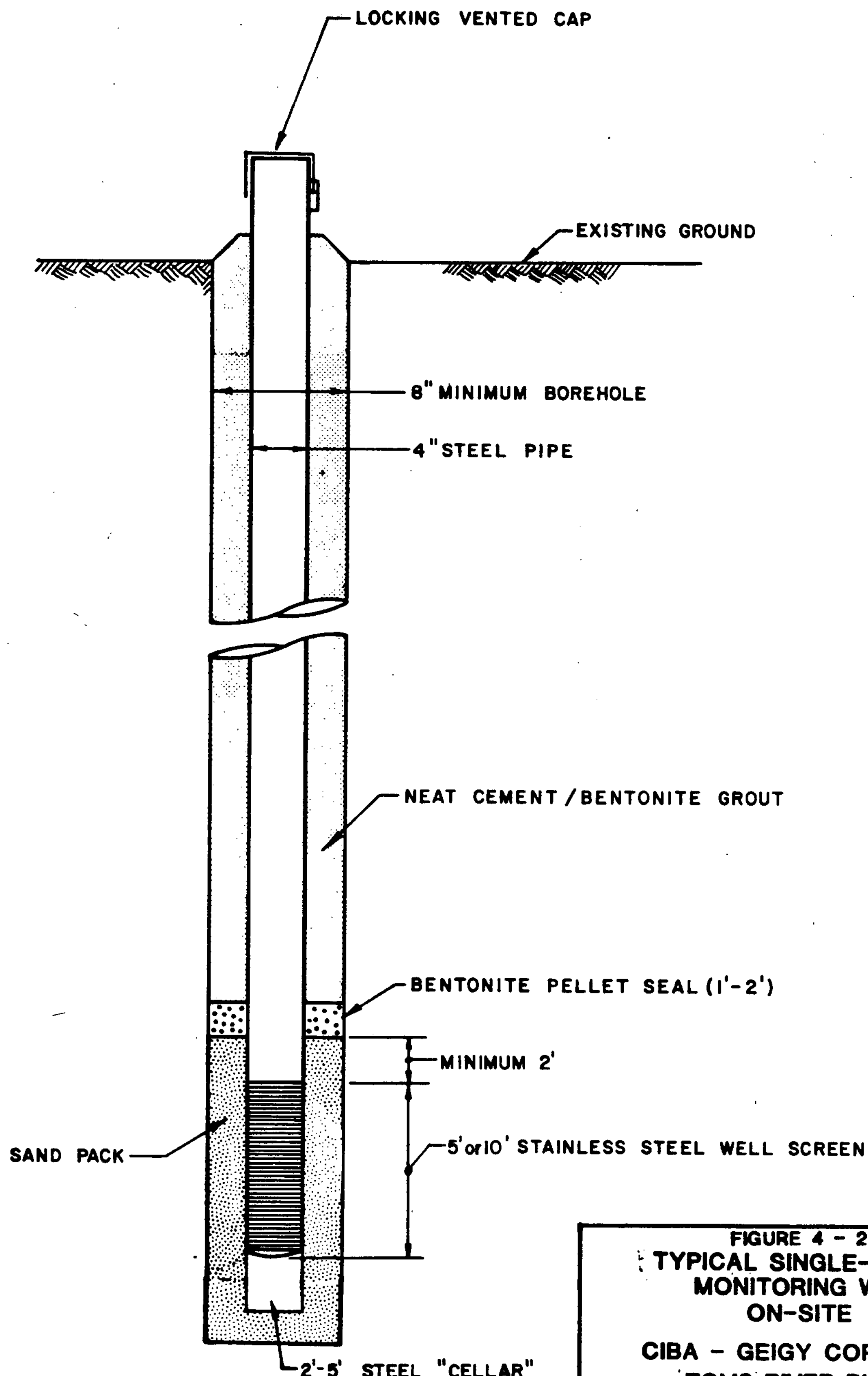


FIGURE 4 - 2
TYPICAL SINGLE-CASED MONITORING WELL ON-SITE

CIBA - GEIGY CORPORATION
TOMS RIVER PLANT

AWARE INCORPORATED WEST MILFORD, NEW JERSEY
NASHVILLE, TENNESSEE

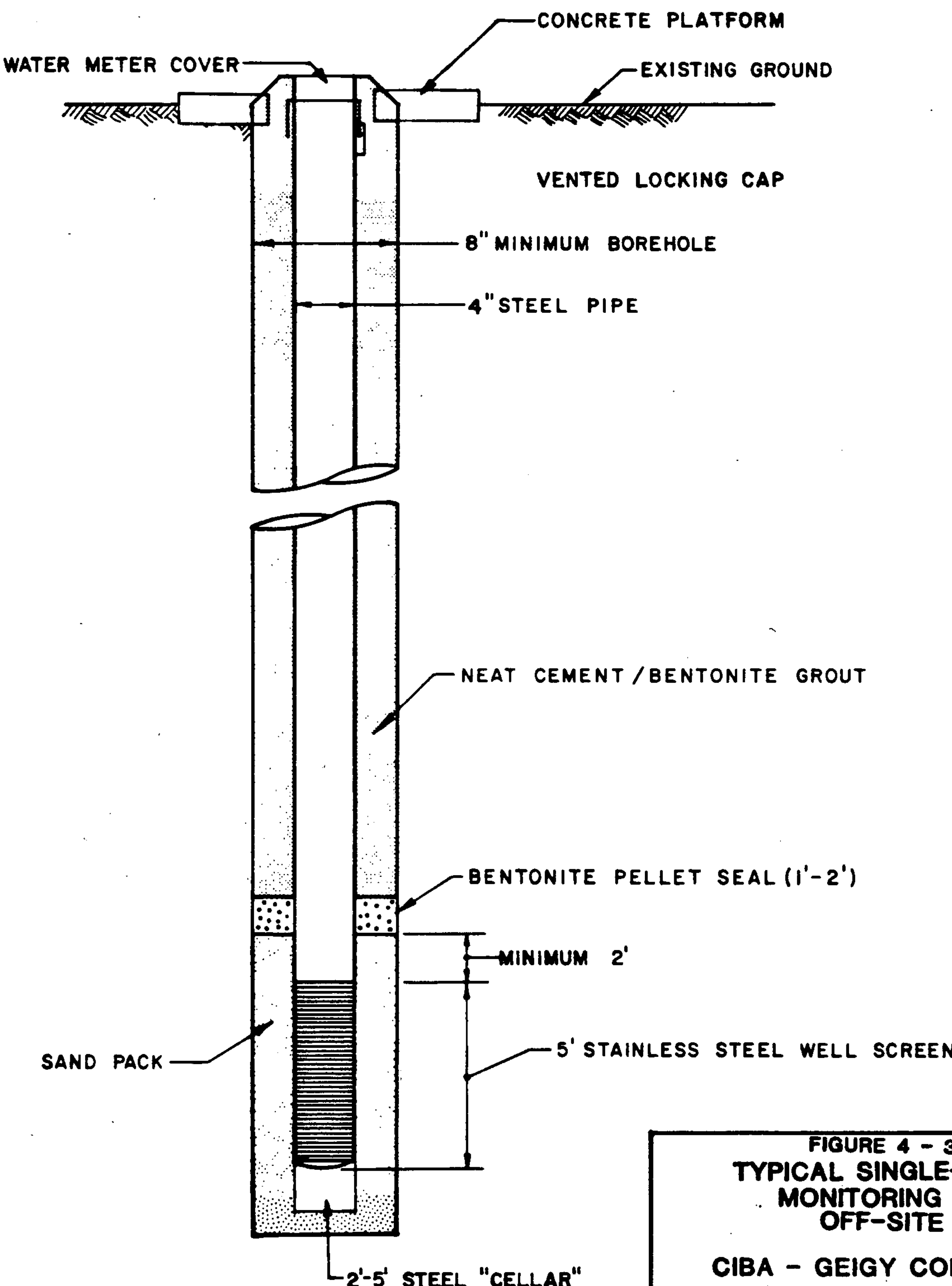


FIGURE 4 - 3
TYPICAL SINGLE-CASED MONITORING WELL OFF-SITE

CIBA - GEIGY CORPORATION
TOMS RIVER PLANT

AWARE INCORPORATED
WEST MILFORD, NEW JERSEY
NASHVILLE, TENNESSEE

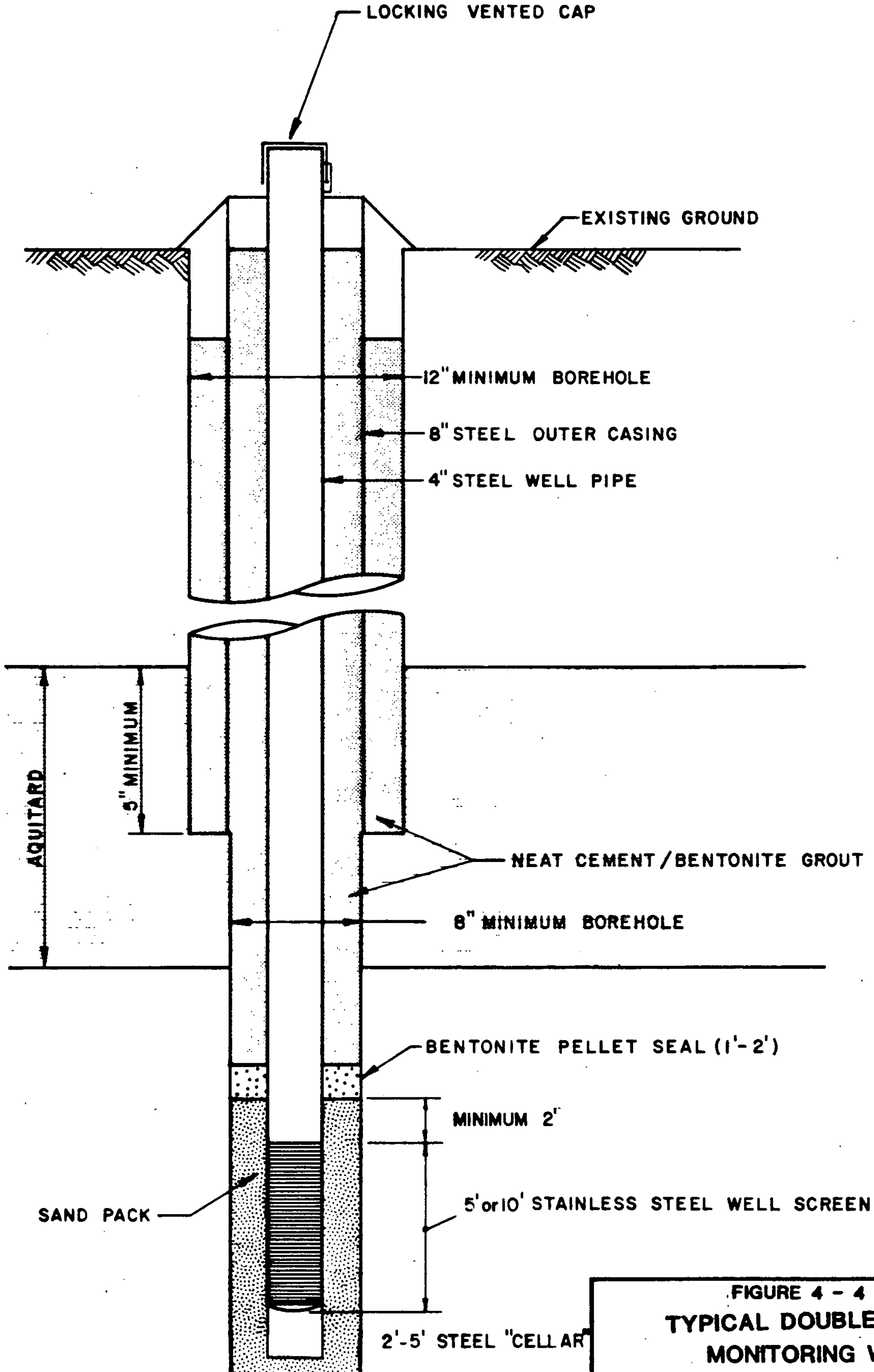


FIGURE 4 - 4

TYPICAL DOUBLE-CASED MONITORING WELL

CIBA - GEIGY CORPORATION
TOMS RIVER PLANT

AWARE INCORPORATED — WEST MILFORD, NEW JERSEY; NASHVILLE, TENNESSEE

TABLE 4-2

SUMMARY OF FIELD HNU ANALYSES
NUS AUGER BORINGS

RI-A-1

Depth (ft.)	HNU (ppm)
4 - 6	ND
6 - 8	5
8 - 10	50
10 - 12	140
12 - 14	100
14 - 16	50

RI-A-2

Depth (ft.)	HNU (ppm)
0 - 2	60
2 - 4	30
4 - 6	NR
6 - 8	30
10 - 12	1
12 - 14	1
14 - 16	0.5

RI-A-3

Depth (ft.)	HNU (ppm)
2 - 4	170
4 - 6	75
6 - 8	20
8 - 10	30
10 - 12	10
12 - 14	15
14 - 16	180
16 - 18	170

RI-A-4

Depth (ft.)	HNU (ppm)
2 - 4	NR
4 - 6	14
6 - 8	13
8 - 10	150
10 - 12	165
12 - 14	4
14 - 16	NR
16 - 18	ND

RI-A-5

Depth (ft.)	HNU (ppm)
2 - 4	ND
4 - 6	ND
6 - 8	15
8 - 10	10
10 - 12	25
12 - 14	65
14 - 16	NR
16 - 18	120

RI-A-6

Depth (ft.)	HNU (ppm)
2 - 4	NR
4 - 6	280
6 - 8	400
8 - 10	140
10 - 12	220
12 - 14	300
14 - 16	500
16 - 18	140
18 - 20	220
20 - 22	5
22 - 24	30
24 - 26	100
26 - 28	60
28 - 30	30
30 - 32	ND
32 - 34	ND
34 - 36	ND

TABLE 4-2 (cont'd)
SUMMARY OF FIELD HNU ANALYSES
NUS AUGER BORINGS

RI-A-7

Depth (ft.)	HNU (ppm)
2 - 4	NR
4 - 6	NR
6 - 8	20
8 - 10	30
10 - 12	120
12 - 14	30
14 - 16	20
16 - 18	NR
18 - 20	NR
20 - 22	45
22 - 24	70
26 - 28	4
28 - 30	10
30 - 32	8
32 - 34	ND
34 - 36	ND
36 - 38	ND

RI-A-8

Depth (ft.)	HNU (ppm)
2 - 4	NR
4 - 6	NR
6 - 8	30
8 - 10	NR
12 - 14	30
14 - 16	5
18 - 20	2
22 - 24	4
24 - 26	100
26 - 28	100
28 - 30	100

NR indicates no recovery
ND indicates not detected

Methylene chloride	Aluminum
Acetone	Arsenic
2-Butanone	Calcium
2-Hexanone	Chromium
4-methyl-2-pentanone	Copper
Toluene	Iron
Chlorobenzene	Lead
Ethylbenzene	Mercury
Xylenes	Vanadium
1,2,4-trichlorobenzene	
Phenanthrene	

Three of the compounds listed above were also detected in quality assurance samples. These compounds are methylene chloride, acetone and 2-butanone. However, the concentrations detected in the actual samples were typically much greater than was found in the quality assurance samples. This suggests that these constituents are components of the waste. Dioxin was not detected in any of the samples tested.

Soil Sampling Program

The soil investigation program conducted by NUS consisted of several discrete sample collection programs focused upon specific areas of the site or upon specific contaminant types. The program included collection of samples from the vicinity of each potential contaminant source area, from within the plant process area, along the major on-site transportation routes, and from the intermittent drainage swales. In addition, samples were collected from a control area located in a portion of the site thought to be free of anthropogenic contamination. The results of the soil sampling program are briefly described below. Specific details of the sample collection procedure, including the actual depths from which the samples were obtained, were not included with the laboratory reports. Accordingly, the discussion that follows is limited to a brief description of the analytical results. The data are included in Volume V.

As might be expected, volatile organics were typically not detected in the soil samples. The semi-volatile fraction, consisting of base/neutral and acid-extractable priority pollutants, was detected at a limited number of sample locations. The locations at which the semi-volatiles were found are shown on Figure 4-5. This figure illustrates the location and the total sum concentration of semi-volatiles detected. The general areas identified include the sludge disposal area, the river lagoon area, the compactor area, the area to the northwest of building 300 and a single location west of the wastewater treatment plant.

Several of the priority pollutant pesticides were detected at various locations on the site, including the control area. Since these compounds are not a part of any known process at the facility, their presence is attributed to intermittent spraying either on a regional or local basis. This would appear to be the case for the DDT and DDE compounds that were detected in the control area. The occurrence of chlordane in the vicinity of the former plastics process area may be a consequence of termite control efforts in this area.

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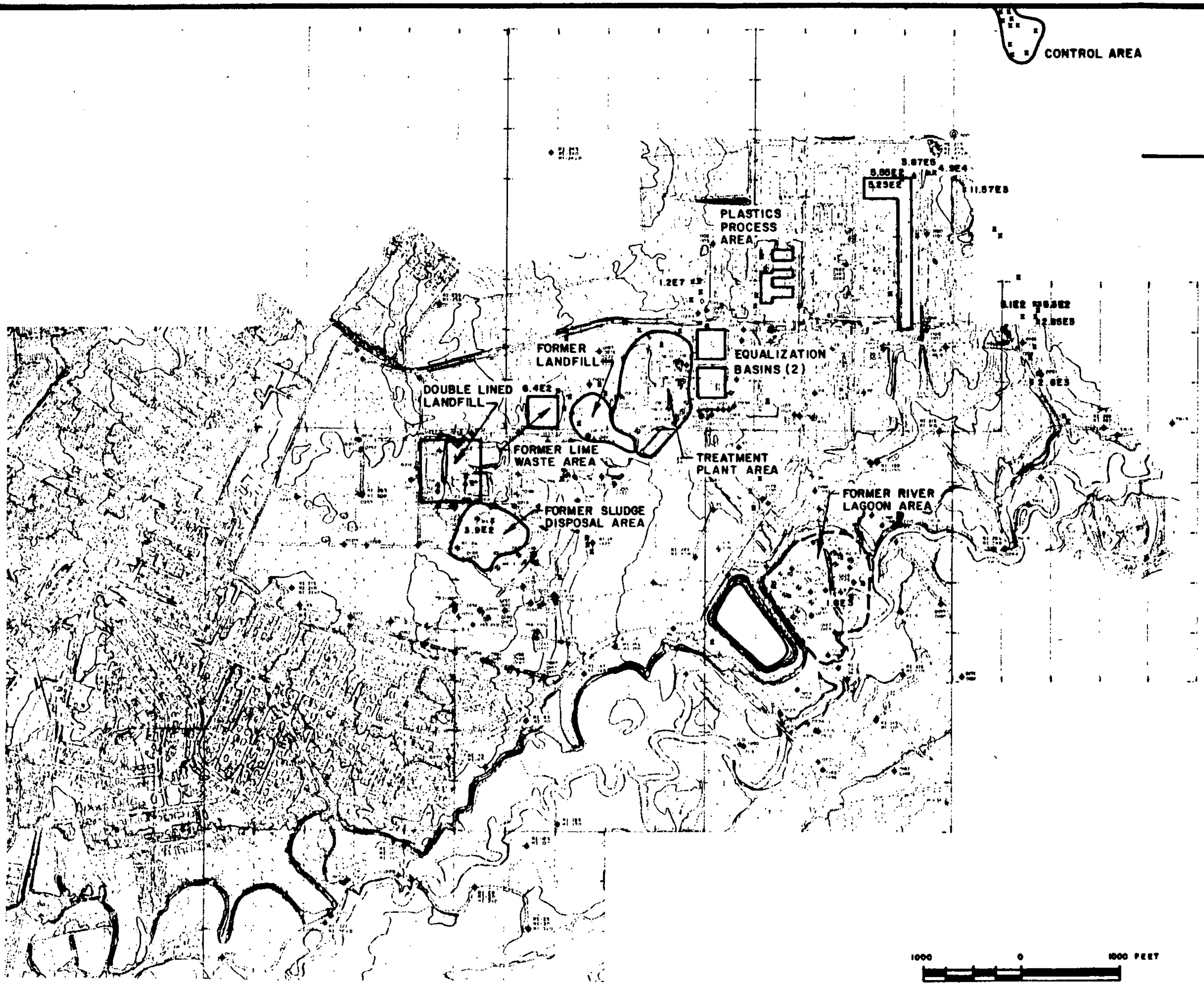


LEGEND:

x APPROXIMATE SOIL SAMPLE LOCATION

RESULTS ARE REPORTED AS THE TOTAL SUM OF DETECTED COMPOUNDS IN UG/KG

FIGURE 4-5

EPA/NUS SOIL SAMPLE RESULTS SEMI-VOLATILES (in ug/kg)

CIBA-GEIGY CORPORATION

TOMS RIVER PLANT

AWARE INCORPORATED — WEST MILFORD, NEW JERSEY — NASHVILLE, TENNESSEE

CIB 004 1860

Polychlorinated biphenyls (PCBs) were detected at three widely scattered locations on the plant site. Two of the locations are near the western limit of the current wastewater treatment plant. The third location is immediately north of building 302. The locations of the samples at which pesticides or PCBs were detected are indicated on Figure 4-6.

Surface Water and Stream Sediment

Surface water and stream sediment sampling programs were performed by NUS for the CERCLA remedial investigation and by JTC Environmental Consultants under the direction of Environ. The NUS sampling program included the collection of surface water samples from nine locations in the Toms River and the collection of stream-bottom sediment samples from five locations within the river channel. Twelve surface water samples, seven standard stream sediment samples, and six dioxin stream sediment samples were collected. Laboratory results are included in Volume VI.

The Environ sampling program included the collection of six sediment and three surface water samples in the marshland area of Winding River Park near the Oak Ridge subdivision. The samples, collected and analyzed by JTC Environmental Consultants, were from an area of surface water ponding and seeps on the western bank of the Toms River flood plain. Two sediment and four surface water samples were also collected from the Toms River in the vicinity of monitoring well RI-9.

The sample results indicate that discharges from the Toms River Plant have a negligible impact upon surface water quality in the Toms River. For example, priority pollutant organic compounds were not detected in the surface water samples with the exception of trichloroethene which was reported at several stations at concentrations below the detection limit. The analysis of sample SW-6, located near Well RI-9, indicated a concentration at 5.6 ppb trichloroethene. Subsequent sampling by Environ at four stations near Well RI-9 found no levels above the detection limit. Several of the surface water stations suggest that iron, sodium, and calcium may be slightly elevated with respect to upstream conditions. By and large, there is no impact on surface water from plant activities.

Each of the six sediment samples collected in the marshland area indicate the presence of volatile organic constituents. Chlorobenzene, tetrachloroethane and trichloroethene were consistently found in the highest concentration, although a number of other parameters were also detected. Concentrations of these three parameters ranged from 7.2 ug/kg of chlorobenzene in sample AS-1 to 5706 ug/kg of trichloroethene in sample AS-3. Sediment contamination in this area is likely due to the discharge of contaminated groundwater to the marshland area. The samples were collected in an area which coincides with the highest groundwater isoconcentration contours of TVPP as shown in Figure 4-47.

Two stream bottom sediment samples were collected in the vicinity of Well RI-9 and also indicated the presence of contamination although at significantly lower concentrations than in the marshland area. A total of six parameters were detected in the two samples, with concentrations ranging from less than the detection limit (5 ug/kg) to a maximum of 392 ug/kg of trichloroethene in sample CS-1. This contamination is also in an area of contaminated groundwater discharge to the Toms River.

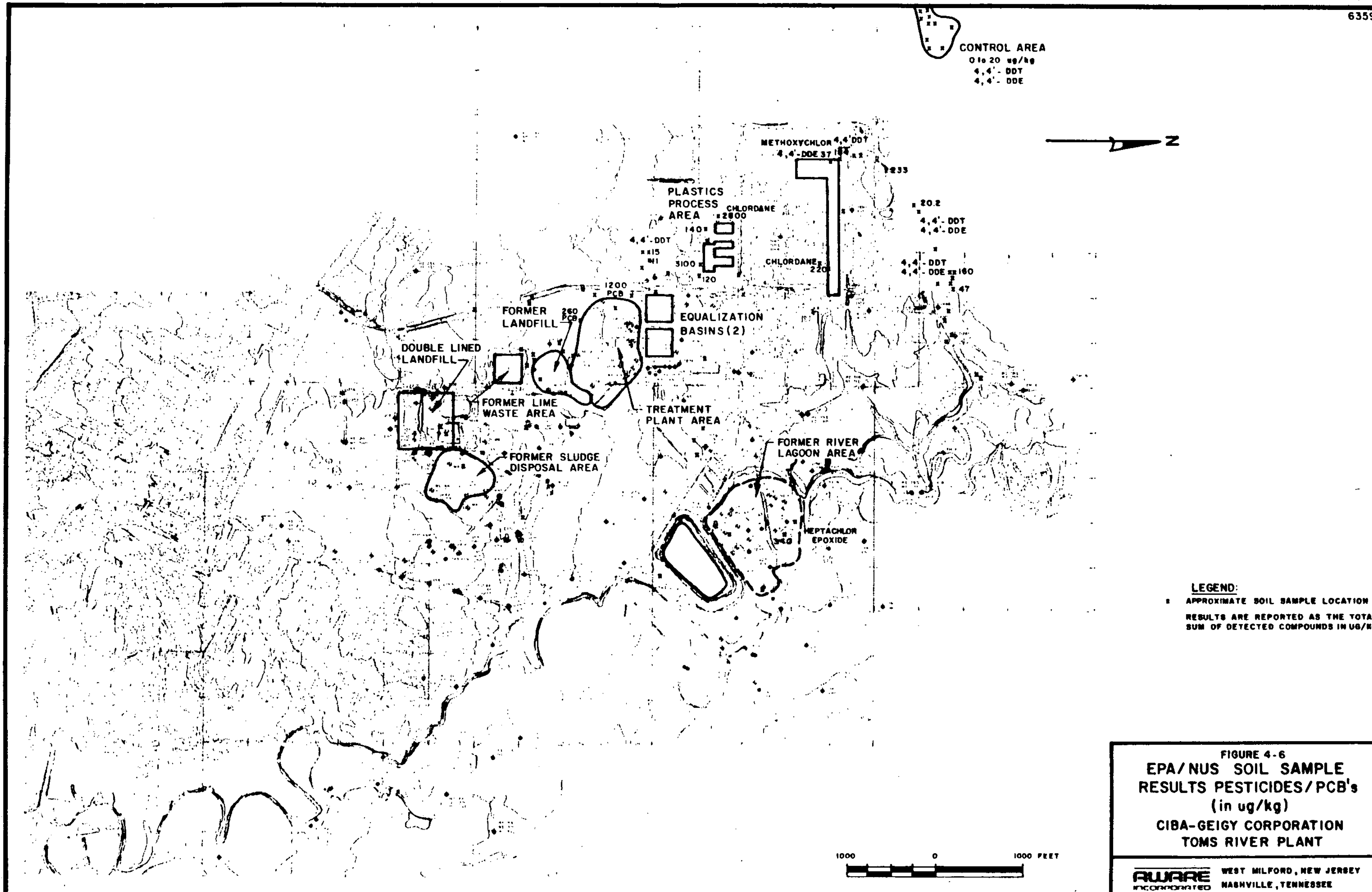


FIGURE 4-6
EPA/NUS SOIL SAMPLE RESULTS PESTICIDES/PCB's (in ug/kg)
CIBA-GEIGY CORPORATION
TOMS RIVER PLANT

None of the priority pollutant organic compounds were found above the method detection limit in the stream sediment samples collected by NUS. Several of the samples had iron concentrations slightly higher than background, while a single sample (S-4) was elevated with respect to copper and zinc. This sample was obtained from the vicinity of the cooling water intake. Dioxin was not detected in any of the stream sediment samples for which it was analyzed.

4.1.2 Supplemental Investigations

In order to further define specific hydrogeologic conditions at the Toms River Plant, five separate investigations were performed. Each investigation addressed a specific concern and provided additional information for the interpretation of hydrogeologic conditions. The scope of each investigation is briefly described below.

Supplemental Winding River Park Investigation

The potential for contamination in Winding River Park opposite the Ciba-Geigy cooling water intake station was first apparent in May 1985 during the drilling of Well RI-9. As a routine part of the supervision of all borings drilled for the Remedial Investigation, soil samples were obtained for field HNU analyses to test for the presence of significant concentrations of volatile organic compounds. In the case of RI-9, the samples indicated a positive HNU response (up to 22 ppm) that increased with increasing depth of the sample.

In response to this finding a series of "mini-piezometers" was installed across the channel of the Toms River at this location. The mini-piezometers were installed in late July at a depth of ten feet beneath the river channel and consist of one-half inch diameter polypropylene tubing with the lower one foot perforated and wrapped with a 200 mesh nylon silkscreen. The mini-piezometers are useful for measurements of both hydraulic head and water quality beneath the river channel. Three installations were performed: one near the southwestern (plant side) bank of the river, one near the channel mid-point (mid-river), and one on the northeastern (park side) bank of the river. The HNU results from these piezometers indicated positive responses in the park side and mid-river stations and non-detection in the plant side station. Hydraulic head measurements indicate that an upward hydraulic gradient on the order of 0.04 exists beneath the entire channel.

Additional evidence of a possible contamination anomaly was provided by a terrain conductivity survey performed by NUS in early April 1985. The raw data was received from USEPA in August and a contour map was prepared of the conductivity data which clearly revealed the presence of an anomaly in the park across from the Former River Lagoon Area and the cooling water intake station (see Figure 4-44). Moreover, upon review of the early investigative work performed by Geonics in 1980, it was noted that such an anomaly had previously been detected but had been deemed to be of minor significance. The extent of the anomaly was subsequently defined by AWARE (refer to Figure 4-52).

The subsequent analyses of split samples (groundwater), taken by JTC in August 1985 and received in early October, confirmed the presence of priority pollutant organic compounds in Well RI-9. The compounds detected and their respective concentrations are outlined in Table 4-3.

TABLE 4-3

ANALYTICAL RESULTS - WELL RI-9

Compound	Concentration (ug/l)
Benzene	76
Chlorobenzene	1680
1,1 Dichloroethane	(3)
1,1-Dichloroethene	14
1,2-Dichloropropane	23
1,1,2,2-Tetrachloroethane	103
Toluene	(4)
1,2-Trans-Dichloroethene	580
Trichloroethene	8400
Aniline	(8)

Values in parentheses indicate concentrations below method detection limit.

In October, a visual inspection of the area around Well RI-9 was conducted to determine if wastes had been placed in this area. No evidence of waste disposal and no indication that the area had been disturbed was found; the area appears to be virgin woodland. A Phase II mini-piezometer survey was then conducted in an attempt to define, in a preliminary fashion, the approximate limits of the contamination.

The additional mini-piezometer survey consisted of the installation of 16 mini-piezometers in the vicinity of RI-9. The intent of the survey was to define the approximate lateral extent of contamination using non-detection on the HNU as the criteria for the plume limit. The survey was intended to quickly identify locations for an additional monitoring well or wells to be installed subsequent to the survey. The locations of the Phase II mini-piezometers are indicated on Figure 4-7.

Based in part upon the findings of the Phase I and II mini-piezometer surveys, four drilling locations were selected within Winding River Park to confirm the limits of contamination in the vicinity of RI-9 and to create a second line of monitoring wells between monitoring wells RI-6 through RI-11 and the Coulter Street area north of the park. The locations of the supplemental monitoring wells are shown of Figure 4-1. The four locations also provided additional data to determine the hydraulic gradient from the northeast side of the Toms River.

At each location, a deep well (60 to 70 feet) screened in the Lower Cohansey water-bearing zone and a shallow well (20 to 30 feet) screened in the Primary Cohansey water-bearing zone were installed. All drilling and well construction services were provided by Delmarva Drilling Company during the period from December 9, 1985 to January 8, 1986. All drilling and well construction activities were performed under the direct supervision of an experienced geologist from AWARE. The geologist selected the actual drilling locations in the field, maintained a log of the encountered subsurface conditions, performed the necessary field tests, and selected the appropriate screen intervals for the monitoring wells. A Failing model 1250 mud rotary drill rig equipped with an eight-inch bottom discharging drag bit was utilized to drill and construct each of the eight wells.

During the drilling of the pilot boring for the deeper well at each location, split-spoon samples were obtained at maximum five-foot intervals in accordance with the procedures of the Standard Penetration Test (ASTM D-1586). A representative sample from each split-spoon was visually classified in the field, sealed with aluminum foil in an eight-ounce sample jar, and allowed to equilibrate to room temperature. An HNU photoionization analyzer was used to measure the relative concentration of total volatile organic compounds in the head space above the sample. The HNU readings were recorded and the samples were logged under AWARE project number 6359. The samples are available for inspection at the West Milford, New Jersey office of AWARE, Incorporated.

Eight wells are designated as Ciba-Geigy monitoring wells 744-0185 through 744-0192. The monitoring wells were constructed using four-inch diameter steel casing with Johnson Co. stainless steel screens, ten-feet in length. The wells were completed with a two-foot section of steel casing to serve as a cellar. A gravel pack, bentonite pellet seal and a grouted annulus were installed in accordance with NJDEP well construction specifications. Specific well

6359

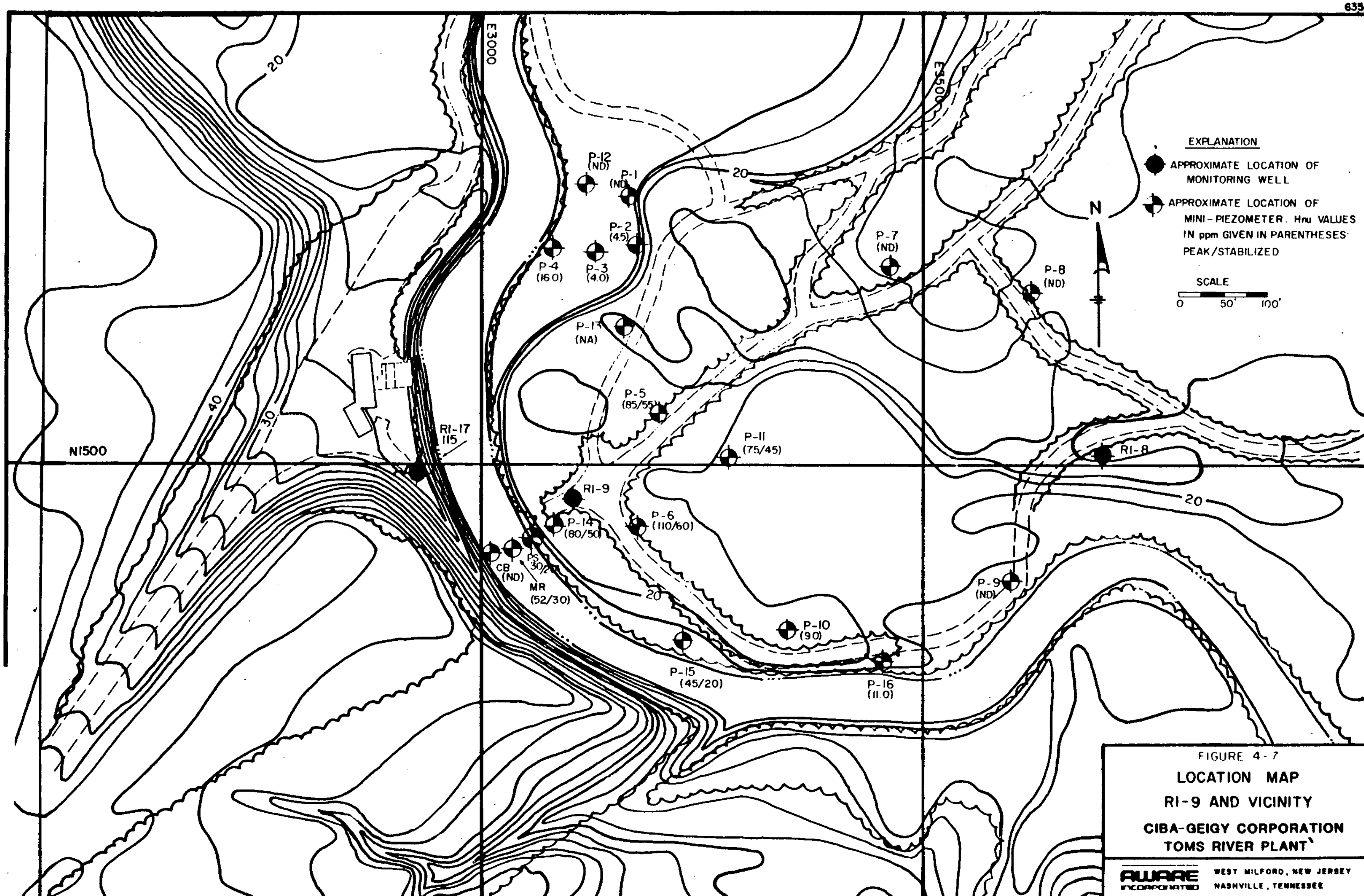


FIGURE 4-7
LOCATION MAP
RI-9 AND VICINITY
CIBA-GEIGY CORPORATION
TOMS RIVER PLANT

construction details are provided on the test boring logs included in Volume II of this document. The screen interval of each well was determined by the depth to the top of Cohansey/Kirkwood Transitional Unit and the depth to the top of the Upper Kirkwood unit. A corresponding "shallow" and "deep" well were placed at these two depths at each of the four locations. The respective screened units are the Primary Cohansey Sand and the Lower Cohansey Sand.

The Equalization Basin Assessment

In this investigation, three on-site drilling locations were selected with the NJDEP's approval to more accurately define the limits and concentrations of the plume believed to be emanating from the Equalization Basin Area. The boring locations also provided additional data for several key areas in the mapping of the subsurface geology of the site as well as for the determination of groundwater flow directions. The investigation was conducted near the cooling water intake station and River Lagoon Area where the plume was believed to be present. A monitoring well couplet was installed at each location at typical depths of 50 to 60 feet and 85 to 90 feet respectively. Drilling and well construction services were provided by W.C. Services from January 13, 1986 through February 4, 1986. A Failing model 1500 mud rotary drill rig equipped with an eight-inch bottom discharging drag bit was utilized to drill the boreholes and install the wells. The split-spoons were driven using a wire-line sampler with sampling conducted through the drill rods.

All drilling and well construction activities were performed under the direct supervision of an experienced geologist from AWARE. The geologist selected the actual drilling locations in the field, maintained a log of the encountered subsurface conditions, performed the necessary field tests, and selected the appropriate screen intervals for the monitoring wells.

During the drilling of the pilot boring for the deeper well at each location, split-spoon samples were obtained at maximum five-foot intervals in accordance with the procedures of the Standard Penetration Test (ASTM D-1586). A representative sample from each split-spoon was visually classified in the field, sealed with aluminum foil in an eight-ounce sample jar, and allowed to equilibrate to room temperature. An HNU photoionization analyzer was used to measure the relative concentration of total volatile organic compounds in the head space above the sample. The samples are available for inspection at the West Milford, New Jersey office of AWARE, Incorporated.

The screened intervals for each well were determined by the depth at which maximum HNU readings were observed. The maximum HNU readings typically corresponded with the top of the Cohansey/Kirkwood Transitional Unit which is the interval at which the three "shallow" wells are screened. The "deep" wells at each location are screened in the Lower Cohansey Sand just above the upper Kirkwood unit.

The six wells (three locations) are designated as Ciba-Geigy monitoring wells 744-194 through 744-199 (Figure 4-1). The monitoring wells were completed with a four-inch diameter steel casing, ten-foot stainless steel screens and a two-foot cellar. The wells were installed in accordance with NJDEP well construction specifications. Specific well construction details are provided on the test boring logs included in Volume II of this document.

The Plant Perimeter Investigation

In this investigation, four additional drilling sites were selected by AWARE to investigate the possibility of contaminant sources in the operating plant area. Each of the four locations was selected after reviewing the groundwater flow paths from the possible plant site sources. A couplet was established at each plant perimeter location to monitor flow from the most probable source areas. The boring locations also contribute more detail to the mapping of the entire site's hydrogeology.

Drilling and well construction services were provided by W.C. Services during the period from February 8, 1986 through March 7, 1986. A Failing model 1500 mud rotary drill rig equipped with an eight-inch bottom discharging drag bit was utilized to drill the boreholes and install the wells.

During the drilling of the pilot boring for the deeper well at each location, split-spoon samples were obtained at maximum five-foot intervals in accordance with the procedures of the Standard Penetration Test (ASTM D-1586). The split spoons were driven using a wire-line sampler with sampling conducted through the drill rods. A representative sample from each split-spoon was visually classified in the field, sealed with aluminum foil, and allowed to equilibrate to room temperature. An HNU photoionization analyzer was used to measure the relative concentration of total volatile organic compounds in the head space above the sample. The HNU readings were recorded and the samples were logged under AWARE project number 6359. The samples are available for inspection at the West Milford, New Jersey office of AWARE, Incorporated.

The screened interval for each well was determined by the depth at which the maximum HNU readings were observed. Maximum HNU readings were typically found just above the Cohansey/Kirkwood Transitional Unit, as was the case in the RCRA investigation. All of the "shallow" wells were screened at the base of the Primary Cohansey Sand at depths ranging from 70 to 80 feet. The "deep" wells were screened in the Lower Cohansey Sand immediately above the contact with the Upper Kirkwood. The screen depth of the deep wells was generally structurally controlled since volatile organics were typically non-detectable.

All drilling and well construction activities were performed under the direct supervision of an experienced geologist from AWARE. The geologist selected the actual drilling locations in the field, maintained a log of the encountered subsurface conditions, performed the necessary field tests, and selected the appropriate screen intervals for the monitoring wells.

The eight plant perimeter wells (four locations) are designated as Ciba-Geigy monitoring wells 744-1100 through 744-1107 and were constructed in accordance with NJDEP specifications. The locations of the plant perimeter monitoring wells are indicated on Figure 4-1. Specific well construction details are provided on the test boring logs included in Volume II of this document.

The Equalization Basin Area/Kirkwood No. 1 Sand Investigation

Three well installation sites were selected to monitor the Kirkwood No. 1 Sand downgradient and upgradient of the Equalization Basins. The investigation was designed to determine if contamination beneath the Equalization Basins had permeated the Upper Kirkwood aquitard and contaminated the Kirkwood No. 1 Sand.

One well was placed on the upgradient (west) side of the basins, with the remaining two wells placed on the downgradient (east) side of the basins. The wells were placed in a triangular array to establish a hydraulic gradient within the No. 1 Sand.

Drilling and well construction services were provided by W.C. Services during the period from March 10, 1986 through April 4, 1986. Two Failing mud rotary drill rigs, a 1500 and a 1250, equipped with an eight- and twelve-inch bottom discharging drag bit respectively, were utilized to drill the boreholes and install the monitoring wells. Split-spoon samples were collected and analyzed using the same procedure established in the previously described supplemental investigations.

The three Kirkwood No.1 Sand wells are designated as Ciba-Geigy monitoring wells 744-1108 through 744-1110. Each well is double-cased with an eight-inch outer casing and a four-inch well casing. A twelve-inch borehole was initially drilled 5 to 10 feet into the upper Kirkwood Formation, and the eight-inch casing was installed and grouted to this depth. With the Primary and Lower Cohansey sand units sealed off, drilling and sampling with an eight-inch bit was continued to the Kirkwood No. 1 Sand. The wells range in depth from 139 to 150 feet. A typical gravel pack, bentonite pellet seal, and grout seal were performed in each of the three well constructions. Johnson Co. 10-slot, stainless steel well screens were used in each well to accommodate the fine-grained nature of the No. 1 Sand. Previous screened intervals in the Cohansey Formation required a larger 20-slot screen size. The screened interval of each well began at the top of the No. 1 Sand and extended ten feet into the unit.

The locations of the Kirkwood No. 1 Sand monitoring wells are indicated on Figure 4-1. Specific well construction details are provided on the test boring logs included in Volume II of this document.

There was no detection of volatile organics beyond the depth of the eight-inch outer casing based on HNU analysis. All soil samples from well 744-1110, located upgradient of the Equalization Basins, were free of detectable volatile organics. Elevated HNU readings were observed in the Primary Cohansey in both downgradient wells 744-1108 and 744-1109.

Dense, Non-Aqueous Phase Liquids Investigation

The review of potential sources of groundwater contamination previously summarized in Section 3.3.2 suggested that the Former Landfill could have been a source of dense, non-aqueous phase liquids. To investigate this possibility, four drilling locations were chosen immediately downgradient of the Former Landfill with the aid of isoconcentration maps produced by AWARE. The sites were selected with the intention of intercepting the areas considered most likely to contain dense non-aqueous phase liquids, i.e., immediately adjacent to the Former Landfill, and both hydraulically downgradient and down the slope of the subsurface structure. Due to the flow behavior of dense non-aqueous phase liquids, attention was focused on low hydraulic conductivity layers within the Primary Cohansey and upon the Cohansey/Kirkwood Transitional Unit.

Drilling and well construction services were provided by W.C. Services during the period from April 7, 1986 through May 2, 1986. A Failing 1250 mud rotary drill rig equipped with an eight-inch bottom discharging drag bit was utilized to drill and sample the boreholes and for the installation of the monitoring wells.

Sampling and well construction inspection was conducted under the supervision of an on-site AWARE hydrogeologist. The split-spoon samples were obtained and analyzed using the same procedure established in the previously described supplemental investigations. The split-spoons were driven using a hydraulically operated wire-line sampler inserted through the drill rods. Continuous samples were taken beginning at depths from 5 to 10 feet below grade to depths below the Cohansey/Kirkwood Transitional Unit (not in excess of 102 feet). Where the borings extended significantly beyond the transitional unit contact, samples were obtained at maximum five-foot intervals to completion. Samples were logged for geological characteristics and were screened with the HNU photoionization analyzer. Zones of suspected organic contamination were subdivided into intervals of one-foot or less for more accurate HNU analysis.

Of the four sampled locations, three were selected for completion as monitoring well couplets, yielding a total of seven wells, designated as Ciba-Geigy monitoring wells 744-1111 through 744-1117. Well 744-1111 is a single well that is a possible candidate for couplet construction at a later date. Each monitoring well was constructed with four-inch diameter, carbon steel well casing and a ten-foot length, 20-slot Johnson stainless steel well screen. The wells were completed in accordance with NJDEP specifications.

Screen intervals were selected based upon the HNU analyses of the continuous soil samples. Two intervals of elevated volatile organics were encountered within the Primary Cohansey sand unit in each of the four drilling locations. The first interval corresponds to the depth of a thin (less than 0.5 feet) layer of ferrous-cemented sand; the second interval corresponds to the top of the Cohansey/Kirkwood Transitional Unit. A third interval with elevated levels of total volatile organics was observed within or above the Cohansey "yellow clay" in borings 744-1111 and 744-1114. The locations of the monitoring wells are indicated on Figure 4-1. Specific well construction details are provided on the test boring logs included in Volume II of this document.

Kirkwood Aquitard Evaluation

The Kirkwood Formation aquitard plays a critical role in the hydrogeologic setting of the Toms River Plant and in particular in the transport of contamination through that system. The Kirkwood aquitard could also conceivably play an important role in remediation of the Toms River site. With respect to groundwater flow, the presence of the Kirkwood aquitard serves to retard to a degree the vertical migration of the plume to lower aquifers such as the Nos. 1 or 2 Sands of the Kirkwood Formation. Insofar as its impact upon remediation is concerned, the Kirkwood Formation aquitard would impact the effectiveness of groundwater recovery systems which may be emplaced in the overlying Primary Cohansey aquifer. Vertical leakage upward through the aquitard as a result of Primary Cohansey groundwater recovery systems serves to reduce the efficiency of such systems. It is therefore critical in the planning of remedial measures that the true hydraulic conductivity of the Kirkwood aquitard be understood. Otherwise the effectiveness of various remedial schemes could be seriously misjudged.

Consequently, it was decided to undertake a comprehensive and multifaceted approach to evaluation of the Kirkwood aquitard at the Toms River Plant. A series of hydraulic conductivity test methodologies were employed in order to enhance the accuracy of the overall study. The methods used include the following:

- Laboratory testing
- In-situ slug testing
- Groundwater dating with naturally-occurring Tritium
- Long-term pump testing

The results of this investigative program are described in Section 4.3.3.

Additional Investigations

In addition to the major supplemental investigations described above, several discrete investigations directed at specific data requirements were also conducted. The additional investigations included a mini-piezometer and seepage meter study of the Toms River flood plain and the active river channel, an additional terrain conductivity geophysical survey designed to supplement the survey conducted by the NUS Corporation, as well as an investigation of the relative ages of the groundwater contained within the Cohansey and Kirkwood formations utilizing the occurrence of tritium. The additional investigations are briefly described below.

Mini-Piezometer and Seepage Meter Study

The mini-piezometer and seepage meter study was conducted to provide estimates of differential head beneath the active channel of the Toms River and in the adjacent marshes, to directly measure the local flux of groundwater inflow to the river, and to assess, in a reconnaissance fashion, the potential for contamination beneath and beyond the active river channel.

The procedures used for the installation of the mini-piezometers were based upon the methods described in Lee and Cherry (1978) but were modified to permit construction of the devices at somewhat greater depths. In order to measure the differential head between the shallow groundwater system and the river, mini-piezometers were installed at a standard depth of approximately ten feet beneath the water level in the river. To achieve this depth of penetration, the discharge from a two-inch diameter centrifugal pump was connected to a one-inch diameter steel pipe section, one foot in length, using a jetting elbow. A gate valve was attached to the pipe section and was used to control the flow of the pump. Five-foot sections of one-inch diameter steel pipe were then attached to the gate valve and served as the jetting stem. With this design a two-man crew was able to achieve a ten-foot depth of penetration except where cemented sandstone was encountered.

The mini-piezometers consist of twelve-foot lengths of one-half inch diameter polypropylene tubing. The lower eight inches of the tubing was manually slotted then wrapped with 200-mesh nylon. This lower section of the tubing serves as the intake or piezometer screen. The piezometer is installed by inserting the tubing into the jetting stem at the appropriate depth. The jetting stem is then carefully removed so that the piezometer screen remains at the desired depth.

A manometer, consisting of a hand suction pump, PVC pipe connectors and dual sections of silicone tubing, was used to accurately measure the differential head between the piezometer and the river level. The pipe connectors were used to form a "T" to which three sections of silicone tubing were attached. The sections were then attached to the suction pump, the piezometer, and to a section of polypropylene tubing placed in the river. When a suction is applied with the hand pump, the height of the two water columns can readily be compared and the differential head calculated.

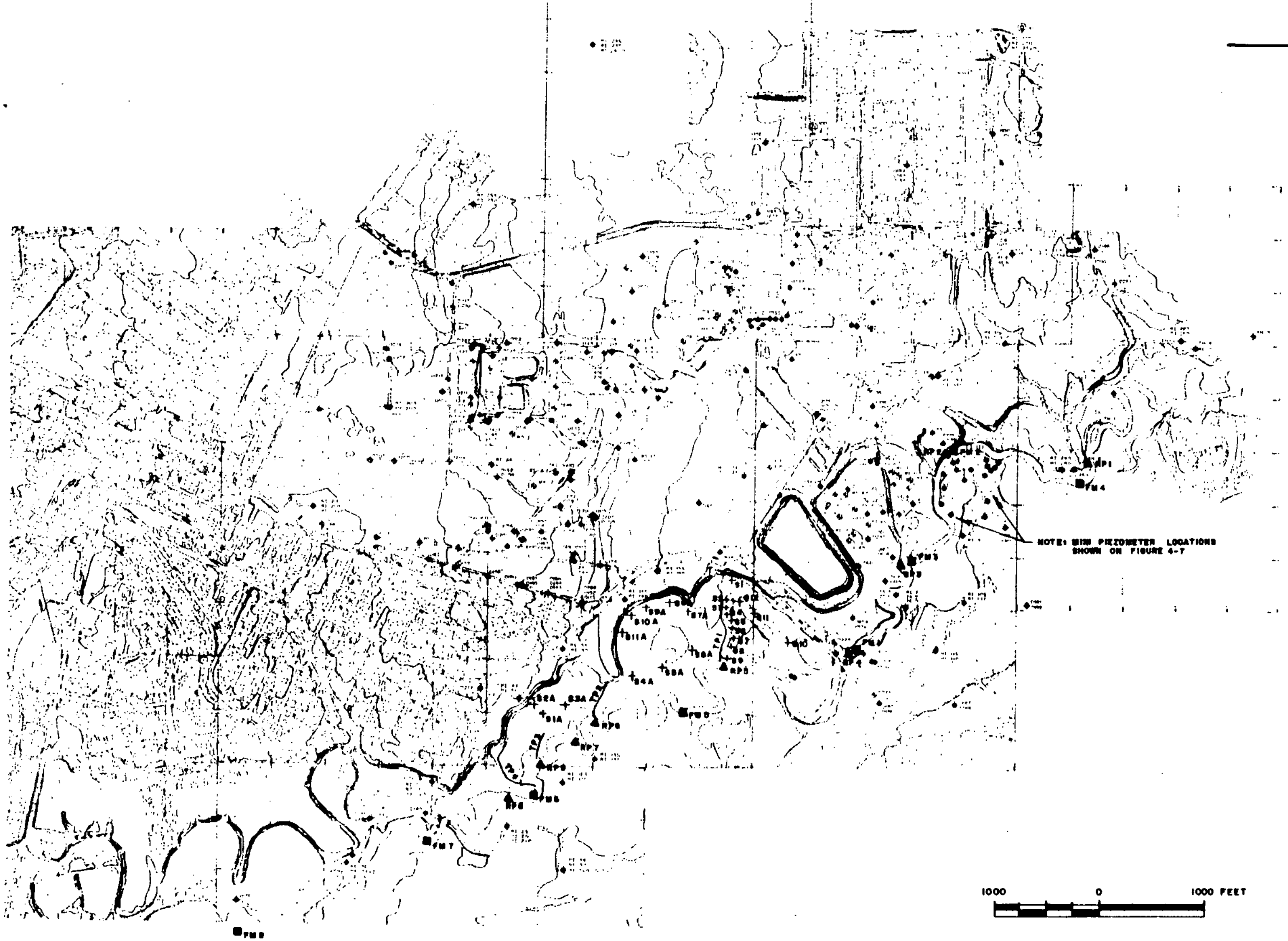
Mini-piezometers were installed at nine locations within the active channel of the Toms River. At each of the locations a piezometer transect, consisting of piezometers placed near either shore and near the center of the active channel, was performed. Several additional mini-piezometer transects were installed in the marshlands adjacent to the river. The locations of the mini-piezometers are indicated on Figure 4-8. Table 4-4 summarizes the differential head data obtained from the mini-piezometers.

Supplemental Terrain Conductivity Survey

A supplemental electromagnetic conductivity study was conducted on the Toms River Plant site using a Geonics EM-34-3 conductivity meter. The EM-34-3 is a two-man, portable, induced conductivity meter with three variable intercoil spacings and two dipolar alignments so as to directly vary the effective depth of exploration. Because the majority of the site consists of non-disrupted forest and the contaminant plumes are known to be conductive, an induced conductivity study is an effective method with which to map contaminated groundwater.

Data was generated at 50-foot intervals along marked trails within the plant site and at selected off-site locations. Data was collected using both the vertical and horizontal coil alignments in order to provide an accurate representation of conductivity throughout the Cohansey sand. A principal constraint on terrain conductivity surveys is interference from buried metal scrap, fencing, pipelines, overhead power lines, and other utility conduits. This factor must be considered during data processing and interpretation.

The most significant readings are obtained at a depth of 0 to 15 meters in the horizontal mode and at a depth of 5 to 30 meters in the vertical mode. By using both dipole alignments, a reasonable representation of both non-saturated and saturated zones was obtained. The latter data was combined with data previously generated by the NUS Corporation. An isopleth contour map of apparent conductivity is presented on Figure 4-43 and is discussed in Section 4.5.2. The field data are presented in Volume V of this document.



LEGEND:

- 0100 — LOCATION AND NUMBER OF MONITORING WELLS WHICH PROVIDE HYDROLOGIC AND GEOLOGIC INFORMATION.
- 0200 — LOCATION AND NUMBER OF PIEZOMETERS WHICH PROVIDE HYDROLOGIC AND GEOLOGIC INFORMATION.
- 21-D — LOCATION AND NUMBER OF MONITORING WELLS, PIEZOMETERS AND BORINGS WHICH PROVIDE ONLY GEOLOGIC INFORMATION.
- ● MINI-PIEZOMETER LOCATION IN THE VICINITY OF RI-9.
- ▲ RIVER MINI-PIEZOMETER TRAVERSE LOCATION
- ■ SEEPAGE METER TRAVERSE LOCATION
- + SOIL SAMPLE LOCATION
- —— MINI-PIEZOMETER TRAVERSE

FIGURE 4-8
APPROXIMATE LOCATIONS OF MINI-PIEZOMETERS AND SEEPAGE METERS

CIBA-GEIGY CORPORATION
TOMS RIVER PLANT
AND VICINITY

AWARE INCORPORATED — WEST MILFORD, NEW JERSEY; NASHVILLE, TENNESSEE

TABLE 4-4

SUMMARY OF MINI-PIEZOMETER AND SEEPAGE METER DATA

Seepage Meters

Seepage Meter Number	Volumetric Seepage Rate ml/min	Measured Seepage Rate ml/min m2	Measured Seepage Rate l/day m2
FLM-1	56.9	336	484
FLM-2	106.2	626	901
FLM-3	51.8	305	439
FLM-4	72.7	428	616
FLM-5	61.7	364	524
FLM-6	80.3	474	681
FLM-7	68.3	403	580
FLM-8	41.8	246	354
FLM-9	43.8	258	372
FLM-10	347.2	2047	2948[1]

NOTES: 1. Visible upwelling noted at this location.

Mini-Piezometers

Piezometer Location	Differential Head[D] A	B	C
1	0.19	NA	0.04
2	0.48	0.32	0.27
3	0.19	0.02	0.21
4	0.04	0.03	0.07
5	0.26	0.15	0.04
6	0.03	0.02	0.01
7	0.06	2.50	2.73
8	0.01	0.01	0.04

NOTES: A indicates piezometers located on the south bank of the river.
B indicates piezometers located approximately at mid-channel.
C indicates piezometers located on the north bank of the river.
D indicates head (in feet) measured in piezometer above that of adjacent marsh.

Environmental Tritium Study

Tritium is a naturally-occurring isotope of hydrogen which has apparently always been found in precipitation due to cosmic ray interactions in the upper atmosphere and other factors. However, with the advent of atmospheric testing of nuclear weapons in the early 1950s, levels of tritium in precipitation rose dramatically (Freeze and Cherry, 1979). By 1963, levels of tritium in precipitation over North America had risen to levels approaching 10,000 tritium units. (A tritium unit is equivalent to 3.2 picocuries per liter.) Tritium levels in precipitation prior to atmospheric testing of nuclear weapons are estimated to be approximately 10 tritium units. With the signing of the nuclear test ban treaty, levels of atmospheric tritium have declined substantially. Currrent levels, however, remain above pre-1950 levels.

Tritium has a half-life of 12.43 years. Accordingly, tritium levels in groundwater resulting from recharge of precipitation will decline by a factor of one-half each 12.43 years. It is therefore often possible to discriminate "old" groundwater which recharged prior to 1950 from more recent groundwater. Where sufficient data exists, it is sometimes possible to estimate the date at which a certain groundwater recharged based upon current tritium levels. Twenty-four monitoring wells and piezometers were sampled for the purposes of tritium analyses during this investigation. The analyses were performed by the Tritium Laboratory of the University of Miami in Miami, Florida and are presented on Table 4-5. Using the enriched technique, a sensitivity of 0.1 tritium units is possible. Assuming that pre-1950 tritium levels were approximately 10 tritium units, relict tritium in groundwater which resulted from precipitation as long ago as roughly 1930, can be detected. Groundwater which recharged prior to 1930 would be expected to exhibit non-detectable levels of tritium at this time. Thus using this dating technique, the vertical velocity of groundwater flow (and thus potential contaminant migration) through the Kirkwood Aquitard could be estimated. It is anticipated that this data would be used in conjunction with other estimates of groundwater velocity.

Abandonment of Monitoring Well 744-0111

During the course of the hydrogeologic investigation, it became apparent that monitoring well 744-0111 was not accurately reflecting potentiometric levels in the Primary Cohansey despite the fact that it appeared to be screened at the proper position. Moreover, water quality data from this well indicated significantly higher levels of contamination than nearby wells screened in the Primary Cohansey. For these reasons, AWARE recommended abandonment of well 744-0111 along with installation of a replacement well couplet. The well couplet was to include a Primary Cohansey monitoring well and an Upper Cohansey monitoring well.

The abandonment was conducted in accordance with NJDEP specifications and included removal of the intact well casing and screen. Monitoring well 111 was constructed using a three-inch ID stainless steel screen attached to a four-inch ID PVC riser. Upon retrieval, the PVC casing was found to be perforated beginning at a depth roughly coincident with the top of the yellow clay unit. Above this point the casing was intact and undamaged; below this point the casing was distorted and perforated in several places. A cross-section of the PVC casing revealed staining of the interior casing wall extending downward from the perforations. The damage to the casing and the observed staining must be

TABLE 4-5

SUMMARY OF TRITIUM DATA

Well No.	Geologic Unit	Final Values
744-0102	PRIMARY COHANSEY	19.5 ± 0.6
744-0109	PRIMARY COHANSEY	20.6 ± 0.7
744-0112	PRIMARY COHANSEY	35.0 ± 1.1
744-0113	PRIMARY COHANSEY	16.9 ± 0.5
744-0126	LOWER COHANSEY	22.6 ± 0.7
744-0127	PRIMARY COHANSEY	9.91 ± 0.35
744-0150	PRIMARY COHANSEY	29.7 ± 0.5
744-0152	PRIMARY COHANSEY	20.5 ± 0.6
744-0163	PRIMARY COHANSEY	18.3 ± 0.6
744-0165	KIRKWOOD	0.30 ± 0.11
744-0179	KIRKWOOD	0.78 ± 0.10
744-0180	KIRKWOOD	-0.02 ± 0.09
744-0181	KIRKWOOD	0.15 ± 0.09
744-0182	KIRKWOOD	0.00 ± 0.07
744-0183	LOWER COHANSEY	60.8 ± 1.7
744-0184	PRIMARY COHANSEY	14.2 ± 0.4
RI-21XD	KIRKWOOD	0.21 ± 0.08
RI-24XD	KIRKWOOD	0.08 ± 0.08

NOTES:
1. Values are reported in tritium units (TU).
2. One tritium unit = 3.2 pCi/kg H_2O.

considered compelling evidence of the prior passage of non-aqueous phase liquids.

Upon separation of the stainless steel screen from the PVC casing, the lower 3.5 feet of the well screen were found to be filled with an asphaltic, granular material. A sample of this material was submitted to SR Analytical for priority pollutants +40 analyses. The analytical results are summarized on Table 4-6 and indicate total priority pollutant organic concentrations in excess of 1.8 percent, with a total organic carbon content of 1.9%. Individual compounds were detected at concentrations ranging up to 1.2 percent. In addition, tentatively identified organic compounds from the NBS library search were detected at a total concentration of 1.8 percent. These data conclusively confirm the existence of non-aqueous phase liquids in the vicinity of the Former Landfill.

4.2 Previous Subsurface Investigations

Ranney Well Investigation

In late 1955 and early 1956, the Ranney Method Water Supply Company conducted an investigation of the feasibility of developing a major water supply on the Toms River Plant site in an area to the northwest of the cooling water intake station. Their investigation included the installation of two, 12-inch diameter test wells, eight test borings and fourteen observation wells. Two separate aquifer pump tests were conducted; the first test involved the lithostratigraphic unit defined in this report as the Lower Cohansey Sand; the second involved the unit we have defined as the Primary Cohansey Sand.

In their report of the aquifer tests dated February 22, 1956, they calculated the transmissibility of the Primary Cohansey to be on the order of 28,400 gallons per day per foot, with an estimated hydraulic conductivity of 1050 gallons per day per square foot (4.4×10^{-2} cm/sec). For the Lower Cohansey they calculated a hydraulic conductivity of 830 gallons per day per square foot (3.9×10^{-2} cm/sec).

Geonics

Geonics, Incorporated of Clinton, New Jersey conducted a series of hydrogeologic and geophysical investigations of the site during the period from 1977 to 1983. They provided the initial interpretations of the occurrence and extent of contamination at several of the potential contaminant source areas. In addition, they supervised the installation of many of the monitoring wells and piezometers that have been utilized in this investigation.

AWARE

Prior to the remedial investigation, AWARE conducted several studies of the hydrogeologic conditions at the site. These studies included interpretation of data generated by Geonics, as well as further investigatory work to more fully define the extent of contamination associated with the Former Landfill and Former Sludge Disposal Area. AWARE also developed a computer model of the Cohansey Formation that was subsequently used to design the Cardinal Drive recovery well system now operating at the site. Monitoring wells beginning with 744-0163 were installed under the auspices of AWARE.

TABLE 4-6

SUMMARY OF ANALYTICAL DATA
WELL 0111 WELL SCREEN SAMPLE

Parameter	Concentration	Units
Tetrachloroethene	560,000	ug/kg
Toluene	200,000	ug/kg
Chlorobenzene	330,000	ug/kg
Ethylbenzene	140,000	ug/kg
1,2-Dichlorobenzene	200,000	ug/kg
1,4-Dichlorobenzene	60,000	ug/kg
Nitrobenzene	270,000	ug/kg
1,2,4-Trichlorobenzene	3,400,000	ug/kg
Naphthalene	190,000	ug/kg
2-Methylnaphthalene	9,200	ug/kg
2,4,5-Trichlorophenol	300,000	ug/kg
Phenanthrene	50,000	ug/kg
Di-N-Butyl Phthalate	720,000	ug/kg
Fluoranthene	13,000	ug/kg
Pyrene	20,000	ug/kg
Bis(2-Ethylhexyl) Phthalate	210,000	ug/kg
Arclor 1242	12,000,000	ug/kg
Arsenic	17,000	ug/kg
Chromium	12,000	ug/kg
Copper	640,000	ug/kg
Mecury	19,000	ug/kg
Nickel	7,300	ug/kg
Selenium	1,300	ug/kg
Zinc	62,000	ug/kg
Phenolics	56,000	ug/kg
Total Organic Carbon	19,000,000	ug/kg

NBS Library Search

Parameter	Fraction	Scan No.	Estimated Concentration	Units
Unknown Aromatic	VOA	502	14,000	ug/kg
1,3-Dimethyl Benzene	VOA	870	100,000	ug/kg
Dimethyl Benzene Isomer	VOA	890	51,000	ug/kg
Unknown C_9 Hydrocarbon	VOA	916	7,100	ug/kg
Dichlorobenzene Isomer	VOA	987	350,000	ug/kg
Dimethyl Benzene Isomer	BNA	479	1,300,000	ug/kg
Unknown Substituted Benzene	BNA	516	460,000	ug/kg
Unknown Alkane	BNA	520	540,000	ug/kg
Unknown Compound	BNA	615	250,000	ug/kg
Unknown Substituted Alkane	BNA	664	1,600,000	ug/kg
Unknown Alkane	BNA	668	660,000	ug/kg
Unknown Substituted Alkane	BNA	695	230,000	ug/kg

TABLE 4-6 (continued)

SUMMARY OF ANALYTICAL DATA
WELL 0111 WELL SCREEN SAMPLE

Parameter	Fraction	Scan No.	Estimated Concentration	Units
Unknown Substituted Alkane	BNA	801	270,000	ug/kg
Trichlorobenzene Isomer	BNA	966	910,000	ug/kg
Unknown Compound	BNA	1161	250,000	ug/kg
Oxybis-benzene Isomer	BNA	1185	290,000	ug/kg
Unknown Compound	BNA	1748	400,000	ug/kg
Unknown Compound	BNA	1801	300,000	ug/kg
Unknown Compound	BNA	2276	1,800,000	ug/kg
Unknown Compound	BNA	2313	3,000,000	ug/kg
Unknown Compound	BNA	2322	710,000	ug/kg
Unknown Compound	BNA	2349	190,000	ug/kg
Unknown Compound	BNA	2359	910,000	ug/kg
Unknown Compound	BNA	2368	740,000	ug/kg
Unknown Compound	BNA	2401	280,000	ug/kg
Unknown Compound	BNA	2971	460,000	ug/kg
Unknown Compound	BNA	2978	920,000	ug/kg
Unknown Compound	BNA	2410	600,000	ug/kg
Unknown Compound	BNA	3223	360,000	ug/kg
Unknown Compound	BNA	3542	230,000	ug/kg

4.3 Geologic Conditions

In this section, the characteristics and extent of the geologic materials encountered within the area under consideration are described. In order to place the site into perspective within the larger geologic framework of the region and to describe the geologic history that led to the formation of the major strata, a brief discussion of the regional geology is presented. The discussion of the regional geology is based upon the published geologic literature for the area, as well as the results of our field investigations. The site-specific geology of the study area is then described in detail based upon our interpretation of the available data.

4.3.1 Regional Geologic Setting

The Toms River Plant is situated within the Atlantic Coastal Plain physiographic province. More specifically, the site is located within the Outer Lowland subprovince, and is underlain by a complex stratigraphic sequence consisting of largely unconsolidated sands, silts, and clays of Cretaceous, Tertiary, and Quaternary age. The unconsolidated sediments of the Coastal Plain unconformably overlie the bedrock of the Piedmont in a southeastward thickening wedge extending from the Fall Line to the subsurface beneath the Atlantic Ocean. The sequence varies in thickness from zero at the northwestern and northern boundaries with the Piedmont to greater than 6,000 feet in the vicinity of Cape May, at the extreme southeastern tip of New Jersey. At the Toms River Plant the Coastal Plain sequence has been shown to be over 2,250 feet in thickness. The Cretaceous and Tertiary age strata typically strike northeast-southwest and dip gently to the southeast at the rate of 10 to 60 feet per mile (Vowinkel and Foster, 1981), with the higher gradient more typical of the basal members of the sequence (Richards, et al., 1962). The overlying Quaternary age deposits are typically flat-lying.

Table 4-7 provides the current stratigraphic correlations for the northern Atlantic Coastal Plain, including New Jersey. Table 4-8 is a generalized stratigraphic section for the New Jersey Coastal Plain. The distribution of the various stratigraphic units in the vicinity of the Toms River Plant is depicted on Figure 4-9.

The Coastal Plain sediments that are of significance to this investigation are those which occur near the top of the sequence, consisting primarily of the Tertiary age Shark River/Manasquan, Kirkwood, and Cohansey Formations and, to a lesser degree the Pennsauken Formation, the Pleistocene age Cape May Formation, and the Holocene alluvial deposits found along the flood plain of the Toms River. These units are described in more detail below, in the order of their deposition.

Shark River/Manasquan Sequence

The Shark River/Manasquan sequence comprises the base of the geologic regime that was directly considered during this investigation. In and near the outcrop area in west-central New Jersey, this sequence may serve as a locally significant aquifer. However, downdip the sequence forms a thick, regionally extensive, composite aquitard that separates the overlying Cohansey/Kirkwood system from the underlying Vincentown and deeper aquifer systems (Zapecza, 1984). The composite aquitard typically consists of green, clayey,

TABLE 4-7

Generalized stratigraphic-correlation chart of the Northern Atlantic Coastal Plain.
(Source: Zapecza, 1984)

ERA	SYSTEM	SERIES	NORTH CAROLINA	VIRGINIA	MARYLAND	DELAWARE	NEW JERSEY	NEW YORK
Cenozoic	Quaternary	Pleistocene	Unnamed	Undifferentiated deposits	Undifferentiated deposits	Undifferentiated deposits	Cape May Formation Undifferentiated deposits	Upper Pleistocene deposits Gardners Clay Jameco Gravel
	Tertiary	Pliocene	Chowan River Fm Yorktown Formation	Chesapeake Group: Chowan River Fm Yorktown Formation	Chesapeake Group: Yorktown Formation	Undifferentiated deposits		Mannetto Gravel (Pliocene?)
		Miocene	Pungo River Formation Belgrade Formation	Chesapeake Group: Eastover Formation St. Marys Formation Choptank Formation Calvert Formation	Chesapeake Group: Eastover Formation / Brandywine Formation St. Marys Formation Choptank Formation Calvert Formation	Chesapeake Group undivided	Pensauken Formation Bridgeton Formation Cohansey Sand Kirkwood Formation	
		Oligocene	River Bend Formation	Unnamed				
		Eocene	Castle Hayne Formation	Chickahominy Formation Piney Point Formation Nanjemoy Formation	Piney Point Formation Nanjemoy Formation	Piney Point Formation Nanjemoy Formation	Piney Point Formation Shark River Formation Rancocas Group: Manasquan Formation	
		Paleocene	Beaufort Formation	Marlboro Clay Aquia Formation Brightseat formation	Aquia Formation Brightseat Formation	Rancocas Group: Vincentown Formation Hornerstown Fm	Rancocas Group: Vincentown Formation Hornerstown Sand	
Mesozoic	Cretaceous	Upper Cretaceous	Peedee Formation Black Creek Formation Middendorf Formation Cape Fear Formation	Mattaponi Formation	Severn Formation Matawan Formation Magothy Formation	Severn Formation Mount Laurel Sand Marshalltown Formation Englishtown Formation Woodbury Clay Merchantville Formation Magothy Formation	Monmouth Group: Tinton Sand Red Bank Sand Navesink Formation Mount Laurel Sand Matawan Group: Wenonah Formation Marshalltown Fm Englishtown Fm Woodbury Clay Merchantville Fm Magothy Formation Raritan Formation	Monmouth Group Matawan Group Magothy Formation Raritan Formation: Clay member Lloyd Sand member
		Lower Cretaceous	Unnamed	Potomac Group: Patapsco Formation Patuxent Formation	Potomac Group: Patapsco Formation Arundel Formation Patuxent Formation	Potomac Group	Potomac Group	
	Jurassic (?)	Upper Jurassic(?)	Unnamed					

modified from Meisler, 1980, fig. 4

TABLE 4-8

Geologic and hydrogeologic units in the Coastal Plain of New Jersey (Source: Zapecza, 1984)

SYSTEM	SERIES	GEOLOGIC UNIT	LITHOLOGY	HYDROGEOLOGIC UNIT	HYDROLOGIC CHARACTERISTICS
Quaternary	Holocene	Alluvial deposits	Sand, silt, and black mud.	Undifferentiated	Surficial material, often hydraulically connected to underlying aquifers. Locally some units may act as confining beds. Thicker sands are capable of yielding large quantities of water.
		Beach sand and gravel	Sand, quartz, light-colored, medium- to coarse-grained, pebbly.		
	Pleistocene	Cape May Formation	Sand, quartz, light-colored, heterogeneous, clayey, pebbly.		
Tertiary	Miocene	Pensauken Formation			
		Bridgeton Formation			
		Beacon Hill Gravel	Gravel, quartz, light colored, sandy.	Kirkwood-Cohansey aquifer system	A major aquifer system. Ground-water occurs generally under water-table conditions. In Cape May County the Cohansey Sand is under artesian conditions.
		Cohansey Sand	Sand, quartz, light-colored, medium to coarse-grained, pebbly; local clay beds.		
		Kirkwood Formation	Sand, quartz, gray and tan, very fine- to medium-grained, micaceous, and dark-colored diatomaceous clay.	confining bed Rio Grande w-bz[1] confining bed	Thick diatomaceous clay bed occurs along coast and for a short distance inland. A thin water-bearing sand occurs within the middle of this unit.
				Atlantic City 800-foot sand	A major aquifer along the coast.
				Composite confining bed	Alloway Clay member or equivalent
	Eocene	Piney Point Formation	Sand, quartz and glauconite, fine- to coarse-grained.	Composite confining bed: Piney Point aquifer	Yields moderate quantities of water locally.
		Shark River Formation	Clay, silty and sandy, glauconitic, green, gray and brown, fined-grained quartz sand.	Composite confining bed	Poorly permeable sediments.
		Manasquan Formation			
	Paleocene	Vincentown Formation	Sand, quartz, gray and green, fine- to coarse-grained, glauconitic, and brown clayey, very fossiliferous, glauconite and quartz calcarenite.	Composite confining bed: Vincentown aquifer	Yields small to moderate quantities of water in and near its outcrop area.
		Hornerstown Sand	Sand, clayey, glauconitic, dark green, fine- to coarse-grained.	Composite confining bed	Poorly permeable sediments.
Cretaceous	Upper Cretaceous	Tinton Sand	Sand, quartz, and glauconite, brown and gray, fine- to coarse-grained, clayey, micaceous.	Composite confining bed: Red Bank sand[2]	Yields small quantities of water in and near its outcrop area.
		Red Bank Sand			
		Navesink Formation	Sand, clayey, silty, glauconitic, green and black, medium- to coarse-grained.	Composite confining bed	Poorly permeable sediments.
		Mount Laurel Sand	Sand, quartz, brown and gray, fine- to coarse-grained, slightly glauconitic.	Wenonah-Mount Laurel aquifer	A major aquifer.
		Wenonah Formation	Sand, very fine- to fine-grained, gray and brown, silty, slightly glauconitic.		
		Marshalltown Formation	Clay, silty, dark greenish gray, glauconitic quartz sand.	Marshalltown-Wenonah confining bed	A leaky confining bed.
		Englishtown Formation	Sand, quartz, tan and gray, fine- to medium-grained; local clay beds.	Englishtown aquifer system	A major aquifer. Two sand units in Monmouth and Ocean Counties.
		Woodbury Clay	Clay, gray and black, micaceous silt.	Merchantville-Woodbury confining bed	A major confining bed. Locally the Merchantville Fm. may contain a thin water-bearing sand.
		Merchantville Formation	Clay, glauconitic, micaceous, gray and black; locally very fine-grained quartz and glauconitic sand.		
		Magothy Formation	Sand, quartz, light-gray, fine- to coarse-grained; local beds of dark-gray lignitic clay.	Potomac-Raritan-Magothy aquifer system: upper aquifer	A major aquifer system. In the northern Coastal Plain the upper aquifer is equivalent to the Old Bridge aquifer and the middle aquifer is the equivalent of the Farrington aquifer. In the Dela. River Valley three aquifers are recognized. In the deeper sub-surface, units below the upper aquifer are undifferentiated.
		Raritan Formation	Sand, quartz, light-gray, fine- to coarse-grained, pebbly, arkosic, red, white, and variegated clay.	conf bd middle aquifer conf bd	
	Lower Cretaceous	Potomac Group	Alternating clay, silt, sand, and gravel.	lower aquifer	
Pre- Cretaceous		Bedrock	Precambrian and lower Paleozoic crystalline rocks, metamorphic schist and gneiss; locally Triassic basalt, sandstone and shale.	Bedrock confining bed	No wells obtain water from these consolidated rocks, except along Fall Line.

[1] Rio Grande water-bearing zone.

[2] ------ Minor aquifer not mapped in this report.

Modified from Seaber, 1965, table 3.

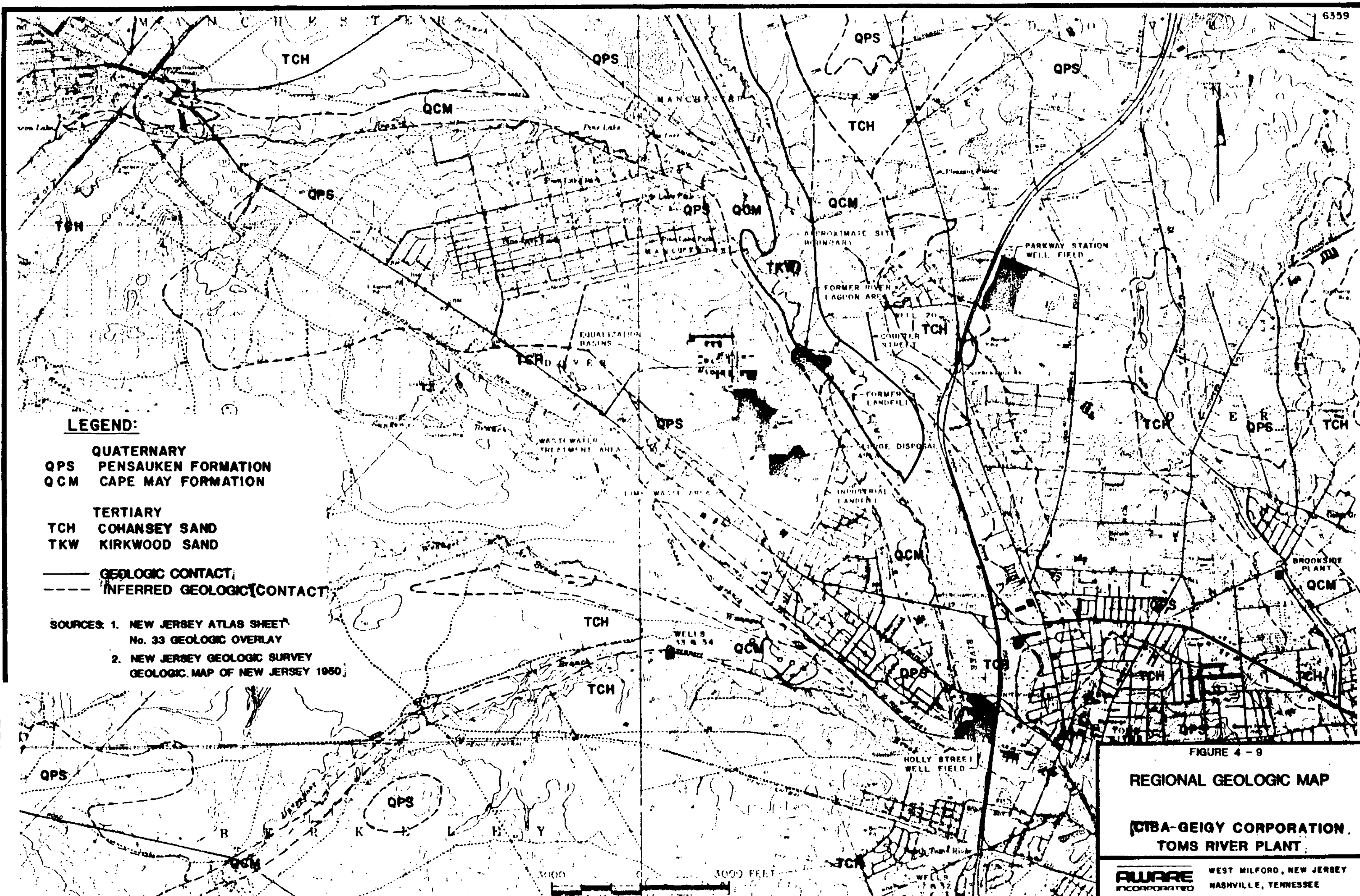


FIGURE 4 - 9

REGIONAL GEOLOGIC MAP

CIBA-GEIGY CORPORATION
TOMS RIVER PLANT

glauconitic, quartz sand containing shark's teeth, ostracods, and pelecypod shells (Anderson and Appel, 1969).

The middle Eocene Shark River Formation directly and unconformably underlies the Kirkwood Formation and is composed of two members. The lower unit, termed the Squankum Member, consists of "clayey silt, silty clay, argillaceous glauconite sand, and quartzose glauconite mudstone" (Wolfe, 1977). The upper Toms River Member consists of micaceous, clayey, glauconitic fine sand and medium to fine-grained quartz sand (Wolfe, 1977). The latter unit has been interpreted as an inner shelf sequence deposited during a regresssion.

The combined thickness of the Shark River/Manasquan sequence in the vicinity of the study area has been estimated to be on the order of 270 feet. This interpretation was derived from a deep test boring performed on the Toms River Plant site and which was logged by Mr. Richard Dalton, a geologist employed by the State of New Jersey. The log for this boring is included in Volume III of this document.

Kirkwood Formation

The Kirkwood Formation, of middle Miocene age, is generally interpreted as a marine or marginal marine depositional sequence and marks the base of a major transgression of the sea (Owens and Sohl, 1969). The Kirkwood unconformably overlies the Eocene age Shark River/Manasquan sequence. The Kirkwood is typically described as a "sparsely fossiliferous, fine, micaceous quartz sand, with black lignite and drab colored clays" (Widmer, 1964). On a regional basis, the Kirkwood can be subdivided into three lithologically distinct members (Isophording and Lodding, 1969):

1. A basal marine clay unit termed the Alloway Clay Member; this member was presumably deposited in the middle-shelf depositional environment.

2. A laminated clayey silt termed the Asbury Park Member. This member has been attributed to a marginal marine environment of marshes, lagoons, and estuaries.

3. An upper unit consisting of lignitic clayey fine sands, grading upward into yellow, orange and white silty sands known as the Greenloch Sand Member. The Greenloch Sand Member both overlies and grades laterally into the Alloway Clay and Asbury Park members, and has been interpreted as a nearshore gulf and/or inner-shelf deposit.

Although the members are clearly distinguishable in outcrop, it is difficult to establish their relationships in the subsurface downdip from the outcrop limit. It would appear that the Greenloch Sand Member or equivalent is present beneath the area of this investigation (Carter, 1978). The Kirkwood reportedly ranges in thickness from about 50 feet at the outcrop to greater than 1000 feet in the Atlantic City area (Anderson and Appel, 1969; Owen and Sohl, 1969). In the vicinity of the Toms River Plant, the Kirkwood achieves a thickness on the order of 80 to 100 feet.

The Greenloch Sand Member has been described, in outcrop, as follows (Isophording and Lodding, 1969):

> "lignitic, clayey sands near the base, with occasional lenses of fine gravel, which grade upward into pastel yellow, orange, and white silty, fine sands displaying prominent Liesegang banding (iron diffusion banding). Near the top the sediments generally coarsen and reflect a final regression of the sea in late middle Miocene time. The coarsening of the sediments in the upper part of the Greenloch Sand Member has made the placing of the Kirkwood-Cohansey contact difficult in wells and has been responsible for the common mis-identification, in outcrop, of this unit for that of the overlying upper Miocene Cohansey Sand. It has also resulted in a controversial argument regarding the conformable or unconformable nature of the Kirkwood-Cohansey contact. This controversy has raged for almost 50 years with the contact being described as everything from a "slight disconformity," involving only a minor regression, to a major unconformity which involved a complete withdrawal of the Miocene sea to beyond the present shoreline."

Water-bearing zones within the Kirkwood Formation are utilized extensively within Ocean County for public water supplies. Well fields operated by the Toms River Water Company include production wells screened in the Kirkwood. The two major well fields are the Parkway Station well field and the Holly Street well field (Figure 3-1).

Cohansey Formation

The Kirkwood is conformably overlain by the late Miocene(?) age Cohansey Formation. The contact is reported to be gradational (Isophording and Lodding, 1969) and presumably represents a change in the depositional environment from the shelf sequence of moderate water depth to shallow, marginal marine conditions. Isophording and Lodding (1969) described the relationship between the Kirkwood and Cohansey Formations as follows:

> "The Cohansey Sand, at least towards its base, represents a continuation of transitional marine deposition which, following a brief transgression, was later coupled with a gradual eastward migration of the shoreline. The local disconformity, seen between the Kirkwood and Cohansey Formations in some outcrops, probably resulted from a minor regression of, at best, a few miles and was of short duration. The conclusion was thus reached that there is no justification for postulating a widespread withdrawal of the sea from the present Coastal Plain, following deposition of the Kirkwood sediments, and that the Cohansey Sand lies, essentially, conformably on the Kirkwood Formation."

The Cohansey Formation can typically be described as a light-colored quartz sand containing minor amounts of gravel, silty and clayey sand, and interbedded clay (Rhodehamel, 1966). Anderson and Appel (1969) describe the Cohansey as follows:

"[The Cohansey] is characteristically a yellowish-brown, unfossiliferous, cross-stratified, pebbly, ilmenitic, fine- to very coarse-grained quartz sand that is locally cemented with iron oxide. White, dark gray, and red kaolinitic clays are interbedded with the sands".

The Cohansey attains a typical thickness in the range of 100 to 250 feet and contains various distinct lithofacies. In the most comprehensive evaluation of the Cohansey to date, Carter (1972) described a total of nine individual lithofacies that he attributed to two distinct facies sequences consisting of a marginal marine, barrier beach complex (Sequence A) and a barrier-protected complex (Sequence B). The relationships between the identified lithofacies and their respective depositional environments are depicted on Table 4-9.

The interpretations advanced by Carter are based, in part, upon a detailed analysis of primary and secondary sedimentary structures, and upon the observed lateral and vertical relationships between the different groups of sediments. The sedimentary structures that were of most use to Carter are often not distinguishable in split-spoon soil samples obtained during drilling. This is particularly the case for cross-bedding or burrowing, sedimentary structures which are typically obliterated during sampling. Other sedimentary structures such as alternating heavy mineral bands, massive (bioturbated) sands, and laminated clays, however, are identifiable in split-spoon samples.

An understanding of the depositional environment of a sedimentary deposit is important from the standpoint of assessing the continuity of the unit, the likely variability in grain-size and thus permeability, and the variability in natural organic content. Each of these factors may be of significance to groundwater flow and ultimately to the migration of contaminants through the system.

The Cohansey Formation is utilized as a source of public water supply in the vicinity of the Toms River Plant. Production wells in the Cohansey that are operated by the Toms River Water Company are indicated on Figure 3-1. In addition, the Toms River Plant operates eight production wells that are screened within the Cohansey. The combined pumpage from the on-site production wells is estimated to be on the order of 3.8 MGD. Finally, the existing purge (recovery) well system located along the Cardinal Drive plant boundary also involves the withdrawal of approximately 0.36 MGD from the Cohansey.

Pennsauken Formation

The late Miocene(?) age Pennsauken Formation unconformably overlies the Cohansey Formation and is well-represented in the Toms River area. The Pennsauken typically consists of a light-colored, pebbly, quartz sand that contains some glauconite and abundant ironstone fragments, the latter presumably derived from iron-cemented sands commonly encountered in the Cohansey. The Pennsauken was derived largely from erosion of the underlying Cohansey sand as well as other Coastal Plain formations further to the west of the study area. Accordingly, the glauconite is interpreted as a secondary product of erosion and redeposition and is not considered to be of environmental significance.

TABLE 4-9

DEPOSITIONAL ENVIRONMENTS OF THE COHANSEY FORMATION
(after Carter, 1972)

Barrier Beach Complex (Sequence A)

Depositional Environment	Lithofacies	Typical Description
Surf Zone	Interbedded Sand & Grit	Well-sorted f-m Sand Poorly-sorted Sand & Gravel
Foreshore	Laminated Sand	Alternating f & c Sand, and/or alt. heavy minerals
Backshore-Dune	Burrowed Laminated Sand	Massive to laminated Sand, heavy mineral & organic content decreasing w/depth
Freshwater Marsh	Peat	Peat and/or organic sand
Saltwater Marsh	Laminated Clay	Yellow-orange, dark gray or pale red-brown clay, often w/ interbedded (washover) silty sand

Barrier-Protected Complex (Sequence B)

Depositional Environment	Lithofacies	Typical Description
Subtidal Channel	Cross-bedded Sand	Cross-bedded sand, minor bioturbation, pebble lag
Intertidal Sand Flat	Burrowed Massive Sand	Multi-colored, massive bioturbated fine Sand
Abandoned Channel	Interbedded Sand and Clay	Thinly laminated multi-color Clay and cross-bedded Sand

The Pennsauken typically forms a mantle of sand and gravel overlying the Cohansey on uplands of moderate elevation (Figure 4-9). It has largely been removed from the lower elevations adjacent to streams and rivers, where it has been replaced by the Pleistocene age Cape May Formation. The formation typically ranges in thickness from 10 to 70 feet, with an average thickness on the order of 20 feet (Wolfe, 1977). The Pennsauken was originally interpreted as a Pleistocene age interglacial deposit (e.g., Lewis and Kummel, 1940). However, in recent years Owens and Minard (1975) argued on the basis of the significant depth of weathering that the formation was of late Miocene or Pliocene age. Little compelling evidence for either interpretation is available at this time.

Cape May Formation

The Pleistocene age Cape May Formation typically consists of sands and gravels, with subordinate clay, distributed along coastal New Jersey and as terraces, levees and overbank marsh deposits along stream and river valleys (Wolfe, 1977). For the most part, the Cape May ranges in thickness from 10 to 30 feet. However, in Cape May County, the formation achieves thicknesses of up to 150 feet (Wolfe, 1977). Four distinct facies have been recognized in the Cape May as follows (Gill, 1962):

1. An estuarine sand facies;
2. An estuarine clay facies;
3. A marine sand facies;
4. A deltaic sand facies;

The estuarine clay facies commonly occurs in tidal inlets and streams fringing the present shoreline, including the Toms River. The clay occurs in the lower reaches of the Toms River as a thin, shallow, organic-rich, dark gray to black silty clay (Anderson and Appel, 1969).

Holocene Deposits

The immediate flood plain of the Toms River contains surficial sediments of Holocene (Recent) age. The sediments consist of typical fluvial sands and gravels, as well as overbank and marsh silts and clays that are rich in organic matter. While these deposits are of limited areal extent, their location and complex stratigraphy can be of local significance to the patterns of groundwater and/or contaminant flow.

4.3.2 Site Geology

In this section, a conceptual geologic model for the Toms River Plant site and vicinity is presented. The model is based upon the constraints imposed by the known regional setting as well as upon our interpretation of data generated by this investigation and by previous studies. With a database consisting of more than 150 test borings and more than 200 wells and piezometers, a high degree of confidence in the conceptual model is possible. The geologic interpretations are described below. As in the previous section, the geologic units are considered in the order of their deposition.

Conceptual Geologic Model

The conceptual model for the Toms River Plant and vicinity consists of three major lithostratigraphic units, eleven subordinate lithostratigraphic units, and eight major hydrostratigraphic units. Table 4-10 summaries the various units and the selected nomenclature. Structural contour and isopachous maps are presented on Figures 4-10 through 4-24 and accompany the descriptions of the individual lithostratigraphic units. Geologic cross-sections are presented at the end of this section as Figures 4-25 through 4-30. Each unit is described in detail below, in the order of deposition.

Shark River/Manasquan Formation

The Shark River/Manasquan Formation was encountered in five of the nine deep borings performed for this investigation (RI-27XD, 744-0179, 744-0180, 744-0181 and 744-0182). The unit was typically described as follows:

> Dark green, glauconitic, m-f SAND, little (+) to and Silt, micaceous, with abundant opaque minerals, medium dense to very dense.

The Shark River/Manasquan Formation is distinguished from the overlying Kirkwood Formation primarily by its significantly higher percentage of glauconite, its sharply higher blow counts, and its distinctly green color. In all likelihood, this unit represents the Toms River Member of the Shark River Formation. However, in the absence of more detailed examination of the thickness and character of this unit we have elected to use the more general "Shark River/Manasquan" terminology. This unit forms the base of the geologic sequence that was directly investigated during this investigation.

Kirkwood Formation

The Kirkwood Formation reportedly overlies the Shark River/Manasquan with a pronounced unconformity (Isophording and Lodding, 1969; Wolfe, 1977). In the limited investigation of the contact afforded during this study, no profound indication of such an unconformity is evident. Possible reworked glauconite in the dark gray Kirkwood fine sands near the contact are the only suggestion of erosion prior to Kirkwood deposition.

The Kirkwood Formation encountered in the study area is a variable unit consisting of interbedded, lignitic fine sand and silt, with clean, well-sorted, fine-grained sands. Five subordinate lithostratigraphic units can be distinguished, and consist, in ascending order, of the Lower Kirkwood, Kirkwood No. 2 Sand, Primary Kirkwood, Kirkwood No. 1 Sand, and the Upper Kirkwood. Each of these units is described below.

Lower Kirkwood

The Lower Kirkwood was encountered in eight of the nine deep borings (RI-3XD, RI-21XD, RI-27XD, 744-0179, 744-0180, 744-0181 and 744-0182) and was penetrated in the five borings that reached the Shark River/Manasquan sequence (RI-27XD, 744-0179, 744-0180, 744-0181 and 744-0182). Where penetrated, the Lower Kirkwood ranged in thickness from 16 feet to 21.5 feet. The Lower Kirkwood was typically described as follows:

TABLE 4-10

CONCEPTUAL GEOLOGIC MODEL
OF THE
TOMS RIVER PLANT AND VICINITY

Major Litho-Stratigraphic Unit	Subordinate Litho-Stratigraphic Unit	Major Hydrostratigraphic Units: Aquifers	Major Hydrostratigraphic Units: Aquitards
Cohansey Formation	Upper Cohansey Sand		
	Yellow Clay/Black Organic Sand Unit		
	Primary Cohansey Sand	Primary Cohansey	
	Cohansey/Kirkwood-Transitional Unit		Cohansey/Kirkwood Transitional Unit
	Lower Cohansey Sand	Lower Cohansey Sand	
Kirkwood Formation	Upper Kirkwood		Upper Kirkwood
	Kirkwood No. 1 Sand	Kirkwood No. 1 Sand	
	Primary Kirkwood		Primary Kirkwood
	Kirkwood No. 2 Sand	Kirkwood No. 2 Sand	
	Lower Kirkwood		Lower Kirkwood
Shark River/ Manasquan Formation	Toms River Member		

Dark gray to brown, SILT & CLAY to fine SAND and SILT, with interbedded green glauconitic SILT to fine SAND, micaceous, loose to medium dense.

The possibility that the Lower Kirkwood as herein defined could, perhaps, represent the top of the Shark River/Manasquan sequence described previously has been considered. However, the interbedded glauconite and the distinct change in density suggest that the Lower Kirkwood represents a reworking of the underlying sequence. Moreover, the regional literature clearly indicates that the basal member of the Kirkwood is a fine-grained sequence marking the transgression of the sea onto Eocene greensands that had been exposed to erosion (Isophording and Lodding, 1969; Wolfe, 1977). For these reasons, it has been decided to define the base of the Kirkwood as the bottom of the unit described in this section and which underlies the sand unit defined as the Kirkwood No. 2 Sand.

The generalized configuration of the upper surface of the Lower Kirkwood is depicted on Figure 4-10. It should be noted that this map is based on just eight data points. Accordingly, it should be considered to provide only a general sense of the surface of the unit. The actual surface is likely more complex than is represented on this map. The unit occurs at elevations ranging from -135.6 to -171.9 feet referenced to mean sea level. The available data were not sufficient to justify preparation of an isopachous map for this unit.

Kirkwood No. 2 Sand

The Lower Kirkwood is conformably overlain by a clean, well-sorted sand defined herein as the Kirkwood No. 2 Sand. The Kirkwood No. 2 Sand was encountered in each of the nine deep borings performed for this investigation (RI-3XD, RI-21XD, RI-24XD, RI-27XD, RI-32XD, 744-0179, 744-0180, 744-0181 and 744-0182). Where penetrated, the unit ranged in thickness from 4.5 feet to 11.1 feet. The unit was typically described as follows:

Light gray to brown c-m-f SAND, trace to little Silt, well-sorted, with green streaks of Silt, very dense.

The Kirkwood No. 2 Sand is distinguished from the underlying Lower Kirkwood and the overlying Primary Kirkwood on the basis of its coarser grain size, its well-sorted character, and by a significant density contrast.

The generalized configuration of the upper surface of the Kirkwood No. 2 Sand is depicted on Figure 4-11. It should be noted that this map is based on just nine data points. Accordingly, it should be considered to provide only a general sense of the surface of the unit. The actual surface is likely more complex than is represented on this map. The unit occurs at elevations ranging from -134.6 to -155.9 feet referenced to mean sea level.

Primary Kirkwood

The Kirkwood No. 2 Sand is conformably overlain by a unit herein termed the Primary Kirkwood. The Primary Kirkwood was encountered in the nine deep borings performed within the study area and was penetrated in each of these borings

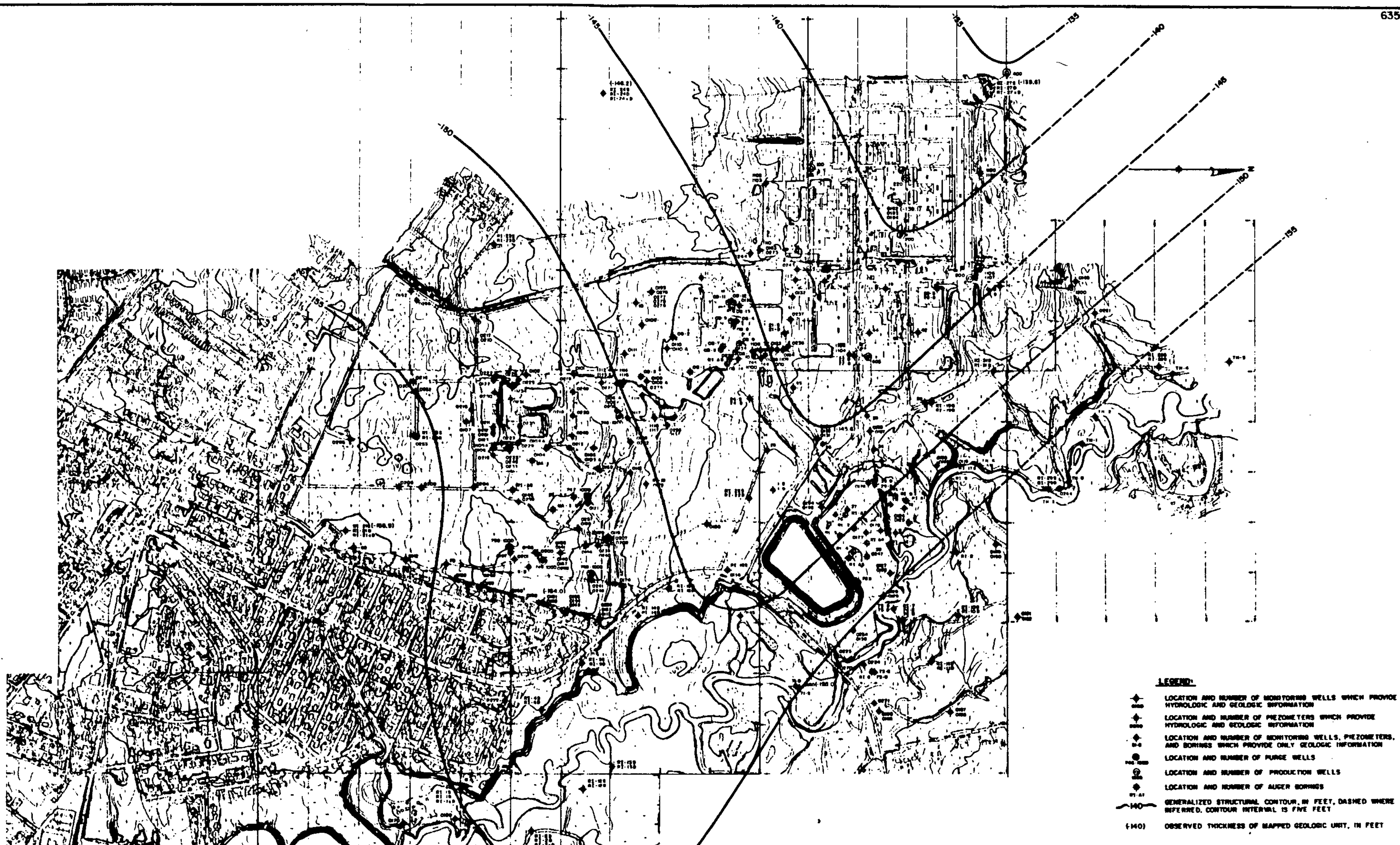


FIGURE 4-10
GENERALIZED STRUCTURAL CONTOUR MAP OF THE TOP OF THE LOWER KIRKWOOD
CIBA-GEIGY CORPORATION
TOMS RIVER PLANT

AWARE INCORPORATED
WEST MILFORD, NEW JERSEY
NASHVILLE, TENNESSEE

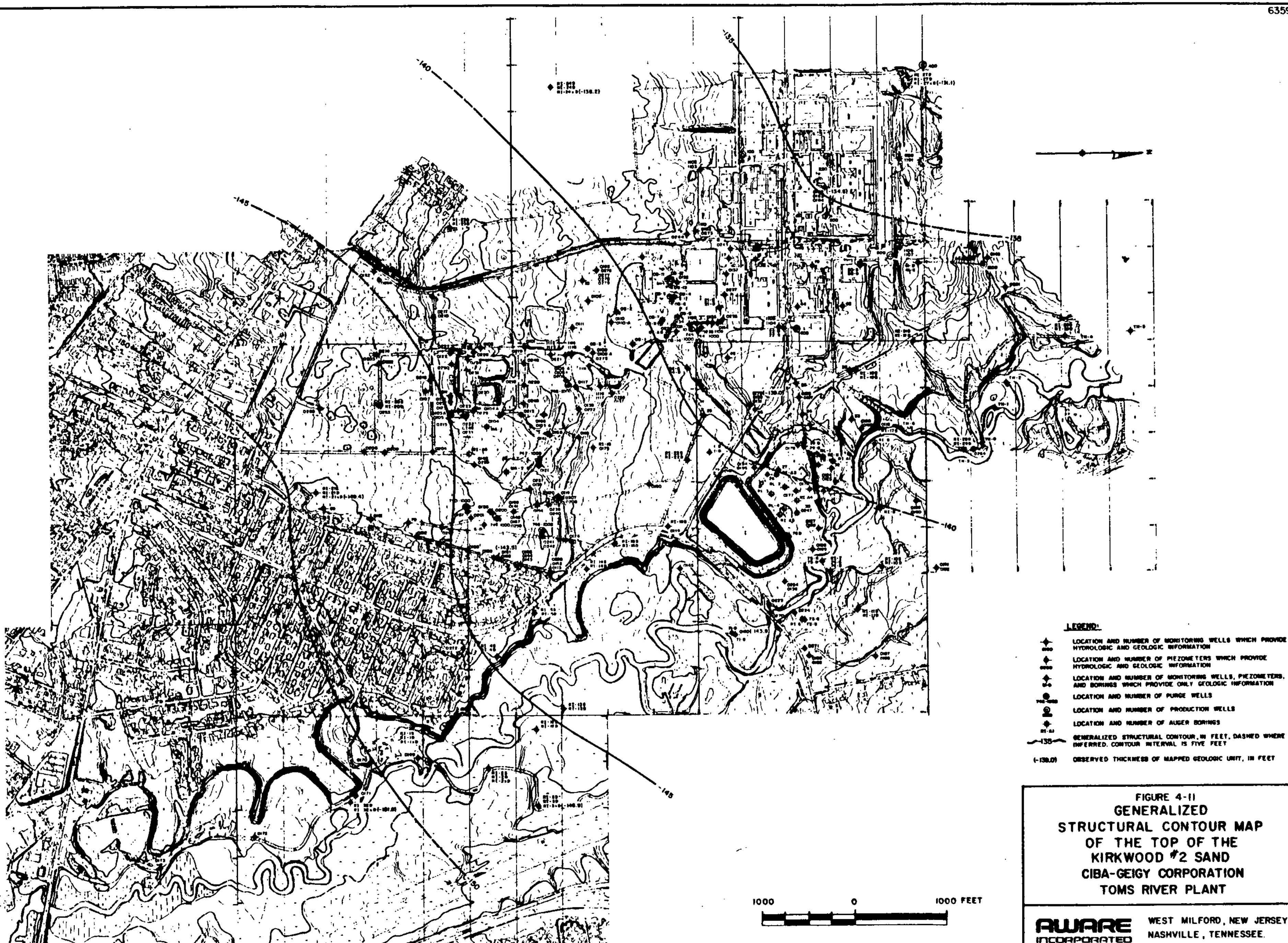


FIGURE 4-11
GENERALIZED STRUCTURAL CONTOUR MAP OF THE TOP OF THE KIRKWOOD #2 SAND
CIBA-GEIGY CORPORATION
TOMS RIVER PLANT

AWARE INCORPORATED
WEST MILFORD, NEW JERSEY
NASHVILLE, TENNESSEE.

(RI-3XD, RI-21XD, RI-24XD, RI-27XD, RI-32XD, 744-0179, 744-0180, 744-0181 and 744-0182). Where penetrated, the unit ranged in thickness from 37.5 feet to 46 feet. The unit was typically described as follows:

> Dark gray to dark brown SILT & CLAY, little fine Sand, to fine SAND and SILT; very micaceous, lignitic, with frequent peat and wood fragments, loose (soft) to medium dense (stiff).

The Primary Kirkwood is distinguished from the underlying Kirkwood No. 2 Sand and the overlying Kirkwood No. 1 Sand by its significantly finer-grained nature, the abundance of lignite and finely fragmented organic matter, and the abundance of mica. The Primary Kirkwood can also be distinguished from the adjacent units by a significant density contrast. For example, blow counts obtained during the Standard Penetration Test are typically in the range of 20 to 30 blows per six inches for both the Primary and Lower Kirkwood units. Blow counts in both the Kirkwood No. 2 Sand and the Kirkwood No. 1 Sand are typically in the range of 50 to 100 blows per six inches.

The generalized configuration of the upper surface of the Primary Kirkwood is depicted on Figure 4-12. Figure 4-13 is an isopachous map for the Primary Kirkwood developed through the conjunctive use of thickness data at individual boreholes and through subtraction of the top of the Kirkwood No. 2 Sand (Figure 4-11) from the top of the Primary Kirkwood (Figure 4-12).

Kirkwood No. 1 Sand

The Primary Kirkwood is conformably overlain by a clean, well-sorted sand defined herein as the Kirkwood No. 1 Sand. The Kirkwood No. 1 Sand was encountered in each of the nine deep borings performed for this investigation (RI-3XD, RI-21XD, RI-24XD, RI-27XD, RI-32XD, 744-0179, 744-0180, 744-0181 and 744-0182) as well as in three supplemental borings (744-1108, 744-1109, 744-1110). Where penetrated, the unit ranged in thickness from 16 feet to 34 feet. Where encountered, the No. 1 Sand ranged in elevation from -68.8 feet to -111.9 feet. The unit was typically described as follows:

> Light gray to brown m-f SAND, trace to little Silt, well-sorted, slightly micaceous, occasionally interbedded with layers of organic Silt, very dense.

The Kirkwood No. 1 Sand can be distinguished from the underlying Primary Kirkwood and the overlying Upper Kirkwood on the basis of its coarser grain size, its well-sorted character, and by a significant density contrast. Typical blow counts within the Kirkwood No. 1 Sand are in the range of 60 to greater than 100 blows per six inches versus 20 to 50 blows per six inches within the adjacent units.

The generalized configuration of the upper surface of the Kirkwood No. 1 Sand is depicted on Figure 4-14.

Upper Kirkwood

The Kirkwood No. 1 Sand is conformably overlain by a lithostratigraphic unit herein termed the Upper Kirkwood. The Upper Kirkwood was encountered in 32 of

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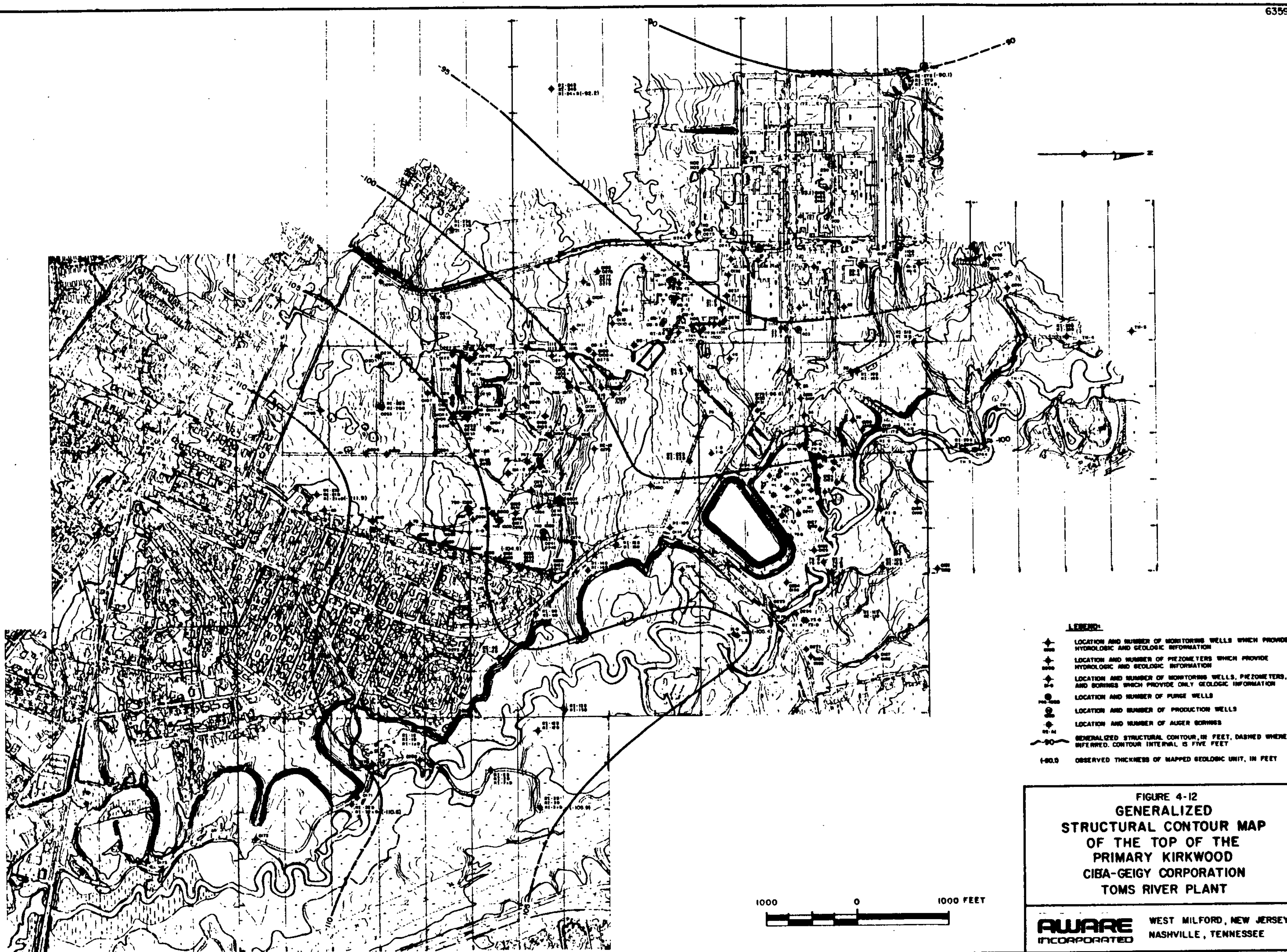


FIGURE 4-12
GENERALIZED STRUCTURAL CONTOUR MAP OF THE TOP OF THE PRIMARY KIRKWOOD
CIBA-GEIGY CORPORATION
TOMS RIVER PLANT

AWARE INCORPORATED
WEST MILFORD, NEW JERSEY
NASHVILLE, TENNESSEE

CIB 004 1895

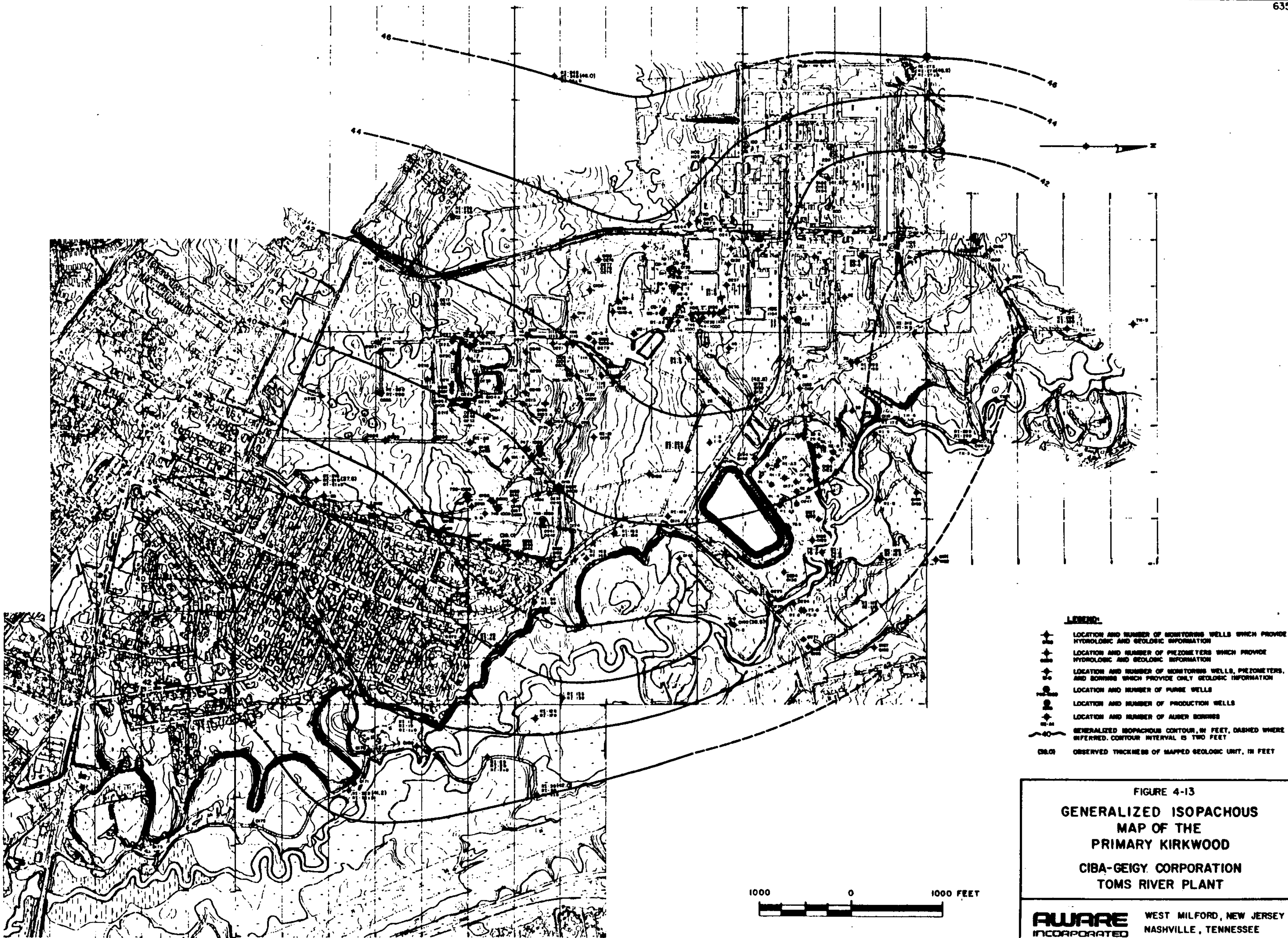
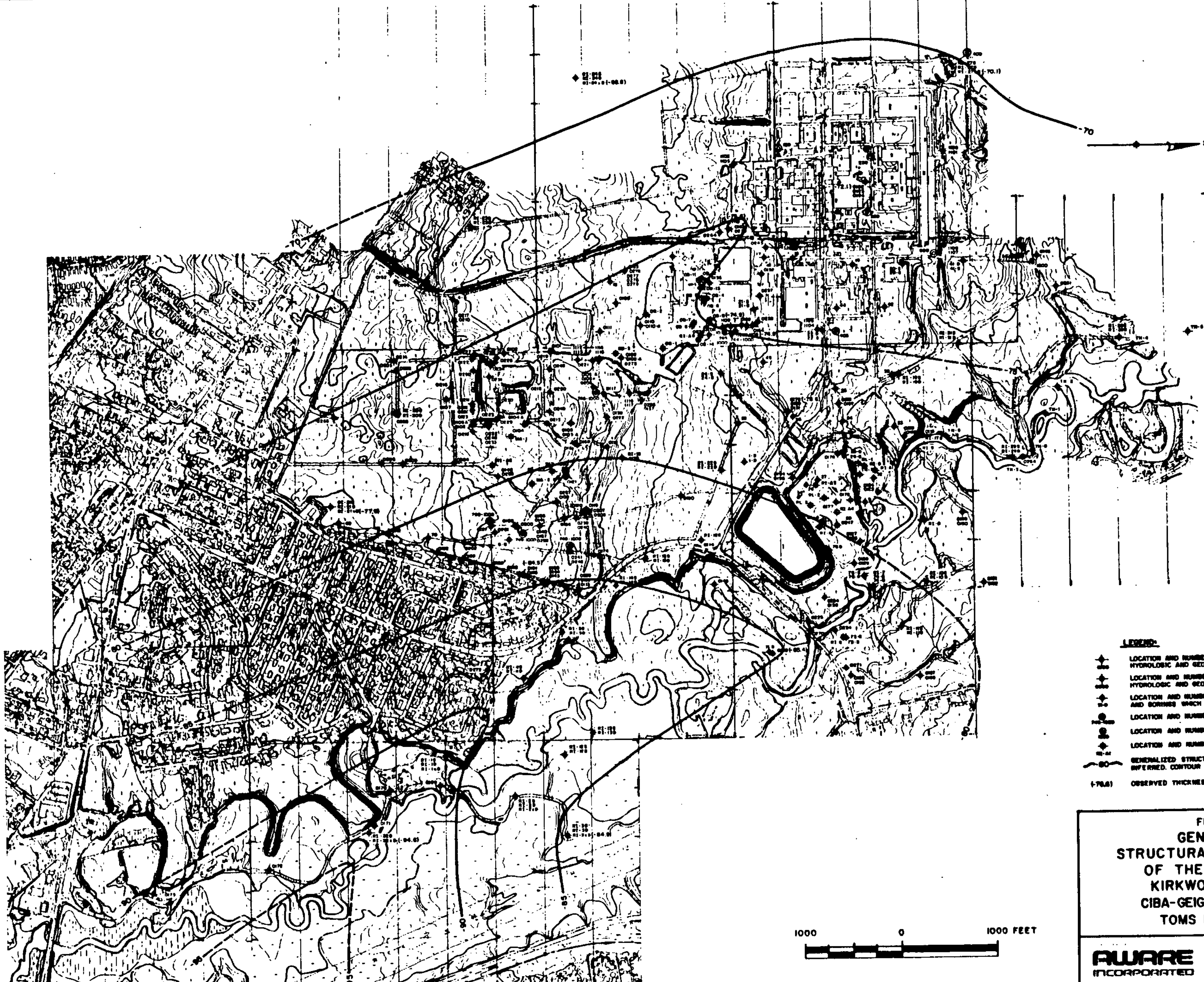


FIGURE 4-13

GENERALIZED ISOPACHOUS MAP OF THE PRIMARY KIRKWOOD

CIBA-GEIGY CORPORATION
TOMS RIVER PLANT

AWARE INCORPORATED
WEST MILFORD, NEW JERSEY
NASHVILLE, TENNESSEE



LEGEND:

- LOCATION AND NUMBER OF MONITORING WELLS WHICH PROVIDE HYDROLOGIC AND GEOLOGIC INFORMATION
- LOCATION AND NUMBER OF PIEZOMETERS WHICH PROVIDE HYDROLOGIC AND GEOLOGIC INFORMATION
- LOCATION AND NUMBER OF MONITORING WELLS, PIEZOMETERS, AND BORINGS WHICH PROVIDE ONLY GEOLOGIC INFORMATION
- LOCATION AND NUMBER OF PURGE WELLS
- LOCATION AND NUMBER OF PRODUCTION WELLS
- LOCATION AND NUMBER OF AUGER BORINGS
- —80— GENERALIZED STRUCTURAL CONTOUR, IN FEET, DASHED WHERE INFERRED. CONTOUR INTERVAL IS FIVE FEET
- (-78.6) OBSERVED THICKNESS OF MAPPED GEOLOGIC UNIT, IN FEET

FIGURE 4-14
GENERALIZED STRUCTURAL CONTOUR MAP OF THE TOP OF THE KIRKWOOD #1 SAND
CIBA-GEIGY CORPORATION
TOMS RIVER PLANT

AWARE INCORPORATED
WEST MILFORD, NEW JERSEY
NASHVILLE, TENNESSEE

the borings performed within the study area and was penetrated in each of the nine deep borings (RI-3XD, RI-21XD, RI-24XD, RI-27XD, RI-32XD, 744-0179, 744-0180, 744-0181 and 744-0182) as well as in three supplemental borings (744-1108, 744-1109, 744-1110). Where penetrated, the unit ranged in thickness from 17 feet to 39.3 feet. The unit was typically described as follows:

> Dark gray to dark brown f SAND and SILT, to f SAND, some Silt; with intervals of dark gray-brown SILT & CLAY to clayey SILT, very micaceous, lignitic, with frequent peat fragments, loose (soft) to medium dense (stiff).

The Upper Kirkwood is distinguished from the underlying Kirkwood No.1 Sand and the overlying Lower Cohansey Sand by its significantly finer-grained nature, the abundance of lignite and finely fragmented organic matter, and the abundance of mica. The Upper Kirkwood can also be distinguished from the adjacent units by a significant density contrast. For example, blow counts obtained during the Standard Penetration Test are typically in the range of 20 to 30 blows per six inches for the Upper Kirkwood unit. Blow counts in the Kirkwood No. 1 Sand and the Lower Cohansey Sand are typically in the range of 50 to 100 blows per six inches.

The generalized configuration of the upper surface of the Upper Kirkwood is depicted on Figure 4-15. Figure 4-16 is an isopachous map for the Upper Kirkwood developed through the conjunctive use of thickness data at individual boreholes and through subtraction of the top of the Kirkwood No. 1 Sand (Figure 4-14) from the top of the Upper Kirkwood (Figure 4-15). Figure 4-17 is an isopachous map for the composite Kirkwood aquitard developed through the conjunctive use of thickness data at individual boreholes and through subtraction of the top of the Kirkwood No. 2 Sand (Figure 4-11) from the top of the Upper Kirkwood (Figure 4-15).

Lower Cohansey Sand

The Upper Kirkwood is conformably overlain by a clean, well-sorted sand defined herein as the Lower Cohansey Sand. The Lower Cohansey Sand was encountered in 32 borings performed for this investigation and was penetrated in each of the 32 borings. The unit was observed to range in thickness from less than 2 feet to 36.4 feet. Elevations ranged from +0.3 feet to -67.6 feet. The Lower Cohansey was typically described as follows:

> Light gray, brown, yellow, and white c-m-f SAND, trace to little Silt, trace f Gravel; to f GRAVEL, little c Sand, well-sorted, slightly micaceous, very dense.

The Lower Cohansey Sand can be distinguished from the underlying Upper Kirkwood and the overlying Kirkwood/Cohansey Transitional Unit on the basis of its coarser grain size, its well-sorted character, and by a significant density contrast. Typical blow counts within the Lower Cohansey Sand are in the range of 60 to greater than 100 blows per six inches versus 20 to 50 blows per six inches within the adjacent units.

The generalized configuration of the upper surface of the Lower Cohansey Sand is depicted on Figure 4-18. Figure 4-19 is an isopachous map for the Lower

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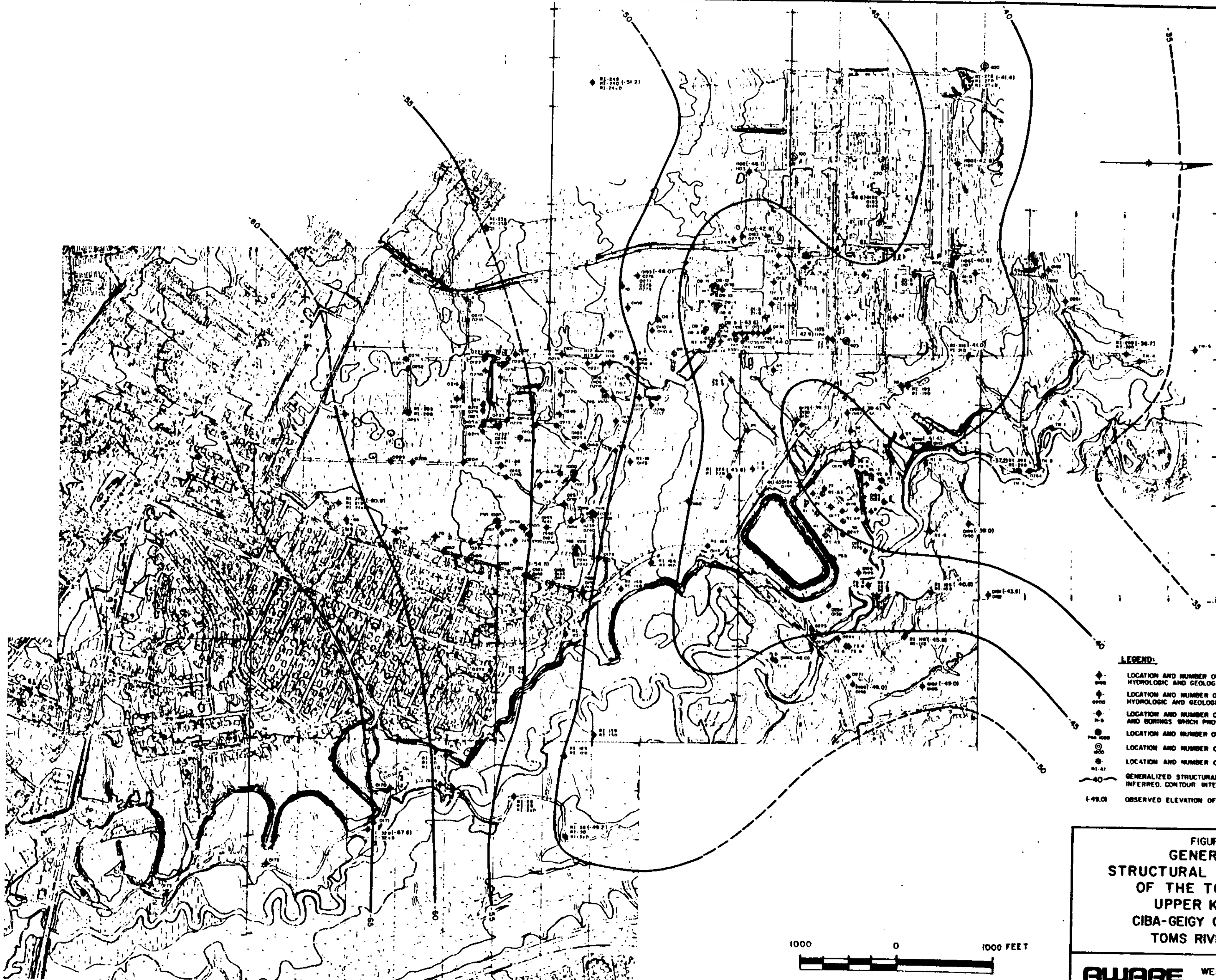

LEGEND:

- LOCATION AND NUMBER OF MONITORING WELLS WHICH PROVIDE HYDROLOGIC AND GEOLOGIC INFORMATION
- LOCATION AND NUMBER OF PIEZOMETERS WHICH PROVIDE HYDROLOGIC AND GEOLOGIC INFORMATION
- LOCATION AND NUMBER OF MONITORING WELLS, PIEZOMETERS, AND BORINGS WHICH PROVIDE ONLY GEOLOGIC INFORMATION
- LOCATION AND NUMBER OF PURGE WELLS
- LOCATION AND NUMBER OF PRODUCTION WELLS
- LOCATION AND NUMBER OF AUGER BORINGS
- —40— GENERALIZED STRUCTURAL CONTOUR, IN FEET, DASHED WHERE INFERRED. CONTOUR INTERVAL IS FIVE FEET
- (-49.0) OBSERVED ELEVATION OF MAPPED GEOLOGIC UNIT, IN FEET

FIGURE 4-15
GENERALIZED STRUCTURAL CONTOUR MAP OF THE TOP OF THE UPPER KIRKWOOD
CIBA-GEIGY CORPORATION TOMS RIVER PLANT

AWARE INCORPORATED
WEST MILFORD, NEW JERSEY
NASHVILLE, TENNESSEE

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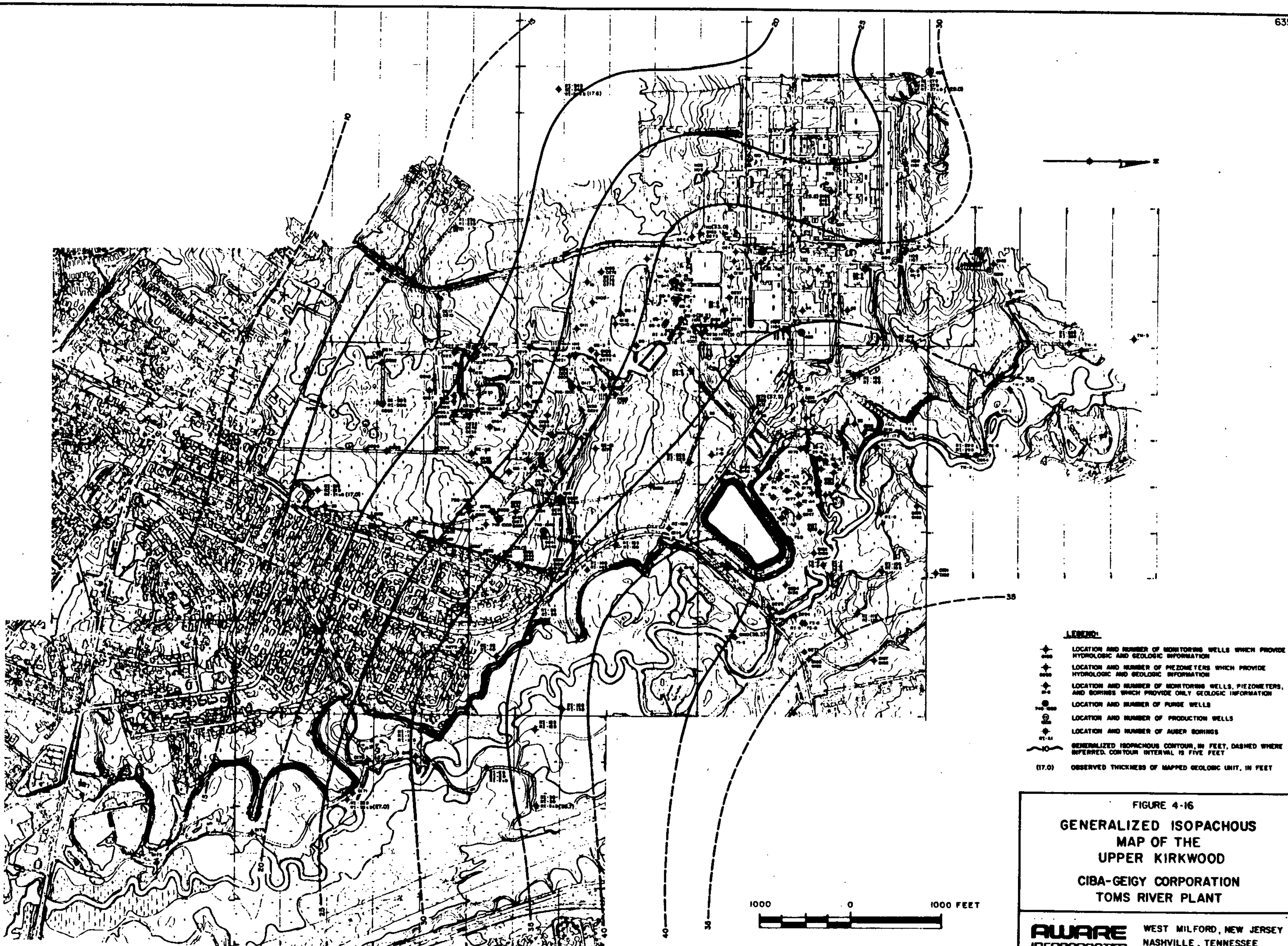


FIGURE 4-16

GENERALIZED ISOPACHOUS MAP OF THE UPPER KIRKWOOD

CIBA-GEIGY CORPORATION
TOMS RIVER PLANT

AWARE INCORPORATED
WEST MILFORD, NEW JERSEY
NASHVILLE, TENNESSEE

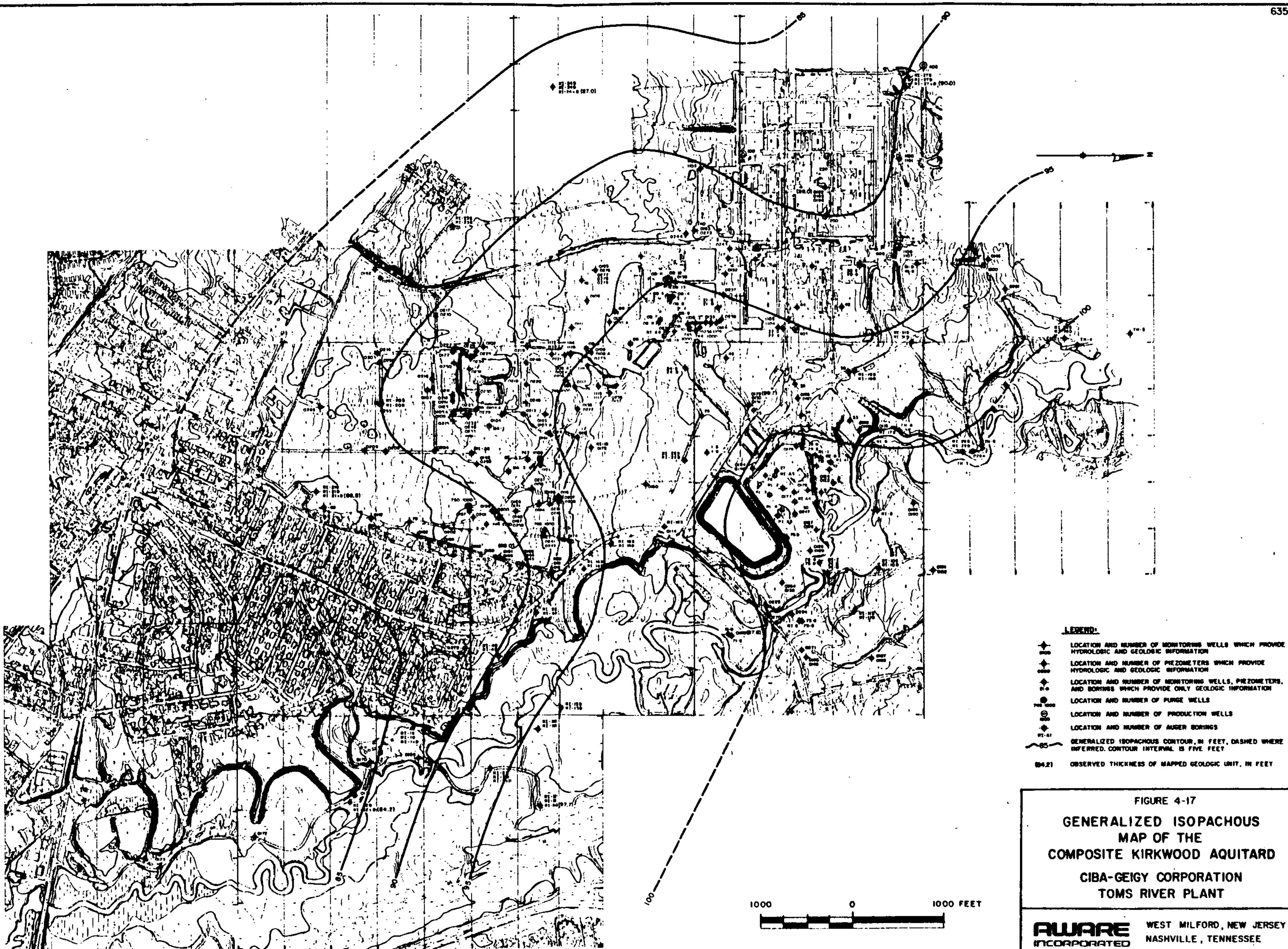


FIGURE 4-17

GENERALIZED ISOPACHOUS MAP OF THE COMPOSITE KIRKWOOD AQUITARD

CIBA-GEIGY CORPORATION
TOMS RIVER PLANT

AWARE INCORPORATED
WEST MILFORD, NEW JERSEY
NASHVILLE, TENNESSEE

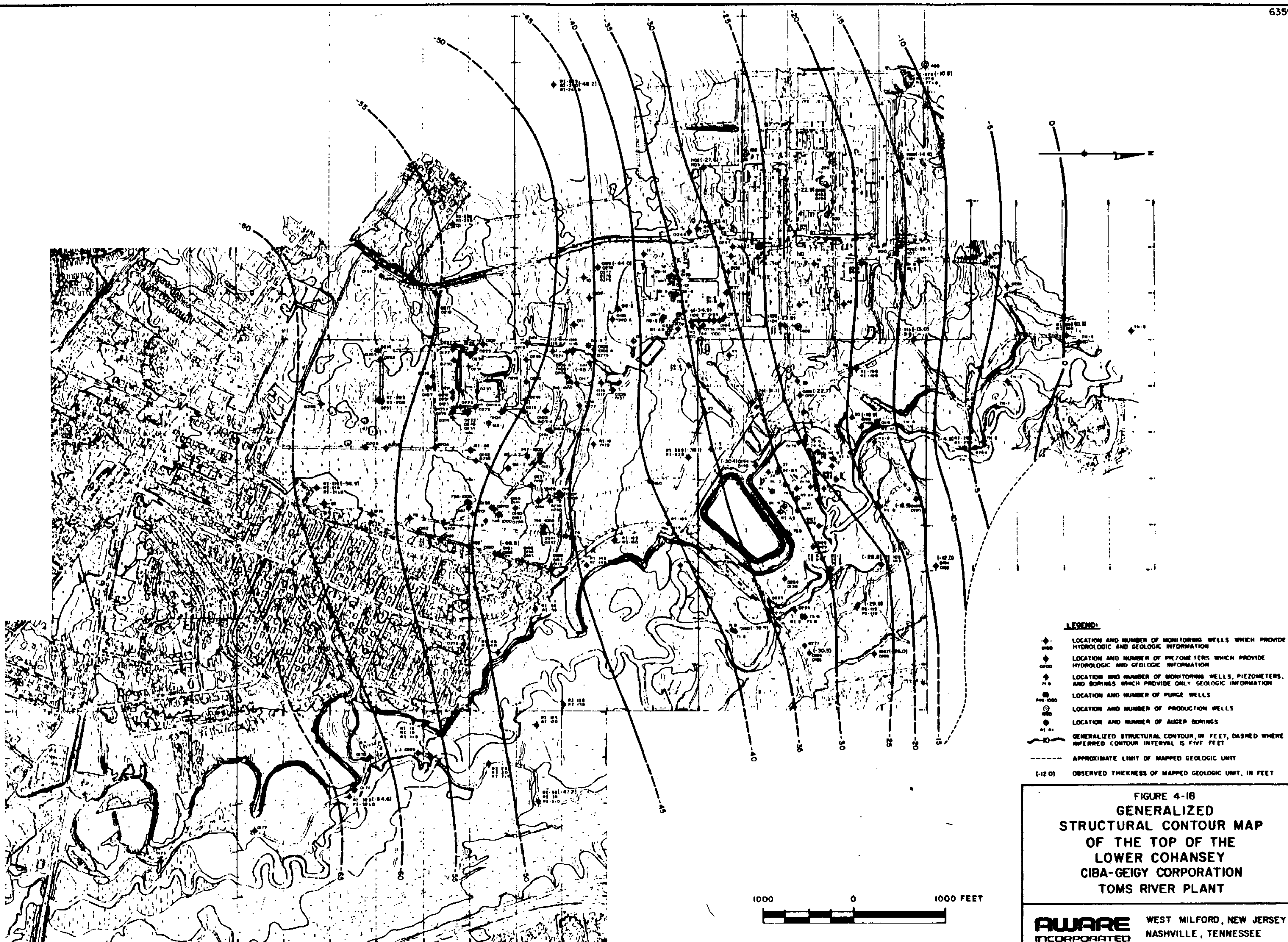
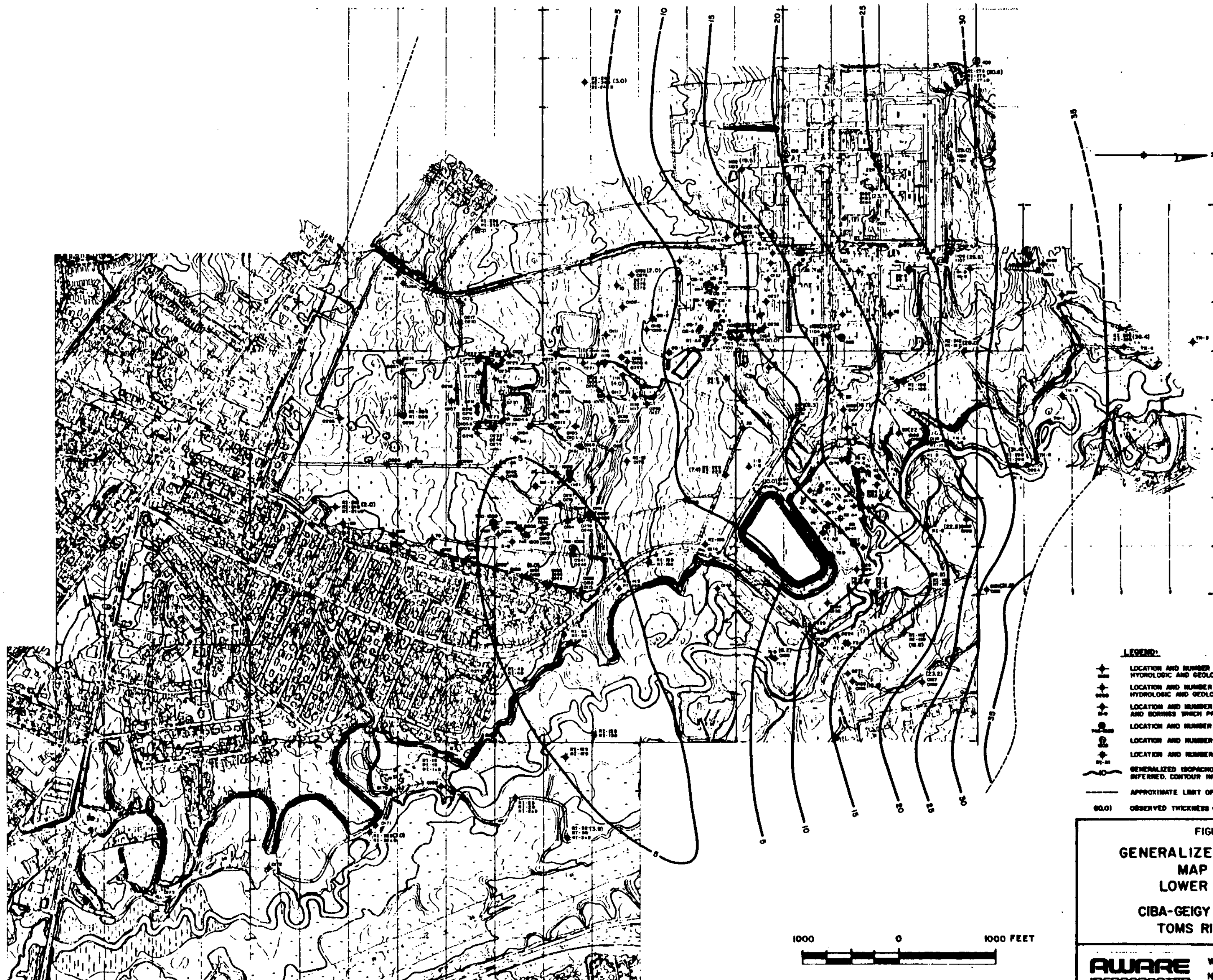


FIGURE 4-18
GENERALIZED STRUCTURAL CONTOUR MAP OF THE TOP OF THE LOWER COHANSEY
CIBA-GEIGY CORPORATION
TOMS RIVER PLANT

AWARE INCORPORATED
WEST MILFORD, NEW JERSEY
NASHVILLE, TENNESSEE



LEGEND:

- LOCATION AND NUMBER OF MONITORING WELLS WHICH PROVIDE HYDROLOGIC AND GEOLOGIC INFORMATION
- LOCATION AND NUMBER OF PIEZOMETERS WHICH PROVIDE HYDROLOGIC AND GEOLOGIC INFORMATION
- LOCATION AND NUMBER OF MONITORING WELLS, PIEZOMETERS, AND BORINGS WHICH PROVIDE ONLY GEOLOGIC INFORMATION
- LOCATION AND NUMBER OF PURGE WELLS
- LOCATION AND NUMBER OF PRODUCTION WELLS
- LOCATION AND NUMBER OF AUGER BORINGS
- GENERALIZED ISOPACHOUS CONTOUR, IN FEET, DASHED WHERE INFERRED. CONTOUR INTERVAL IS FIVE FEET
- APPROXIMATE LIMIT OF MAPPED GEOLOGIC UNIT
- (0.0) OBSERVED THICKNESS OF MAPPED GEOLOGIC UNIT, IN FEET

FIGURE 4-19

GENERALIZED ISOPACHOUS MAP OF THE LOWER COHANSEY

CIBA-GEIGY CORPORATION
TOMS RIVER PLANT

AWARE INCORPORATED
WEST MILFORD, NEW JERSEY
NASHVILLE, TENNESSEE

Cohansey Sand developed through the conjunctive use of thickness data at individual boreholes and through subtraction of the top of the Upper Kirkwood (Figure 4-15) from the top of the Lower Cohansey Sand (Figure 4-18).

The Lower Cohansey Sand is discontinuous beneath the area of investigation and marks the initiation of the transition from Kirkwood deposition to Cohansey deposition. To the west and northwest the Lower Cohansey both thickens and becomes cleaner and coarser-grained; to the east and southeast the unit thins (Figure 4-19) and becomes finer-grained and more poorly-sorted. In the southeastern portions of the study area, in fact, the Lower Cohansey is distinguishable only as an increase in the coarse sand/fine gravel fraction within a matrix of typical Kirkwood-like, very micaceous, fine sand and silt.

We have defined this unit as a subordinate member of the Cohansey Formation on the basis of its lithology as well as upon its lateral and vertical relationship to the Kirkwood and Cohansey Formations. Our interpretation of cross-sectional relationships (see Figure 4-31) suggests that to the northeast the overlying Kirkwood/Cohansey Transitional Unit is absent, resulting in a continuous and direct contact between the Primary and Lower Cohansey sands as herein defined. We interpret the Lower Cohansey Sand to Kirkwood/Cohansey Transitional Unit sequence to be the result of a local regression/transgression event of relatively minor extent and duration. The change in character of this unit beneath the area of concern has significant implications for the assessment of potential contaminant migration pathways. These implications are discussed in Section 4.5.2 of this report.

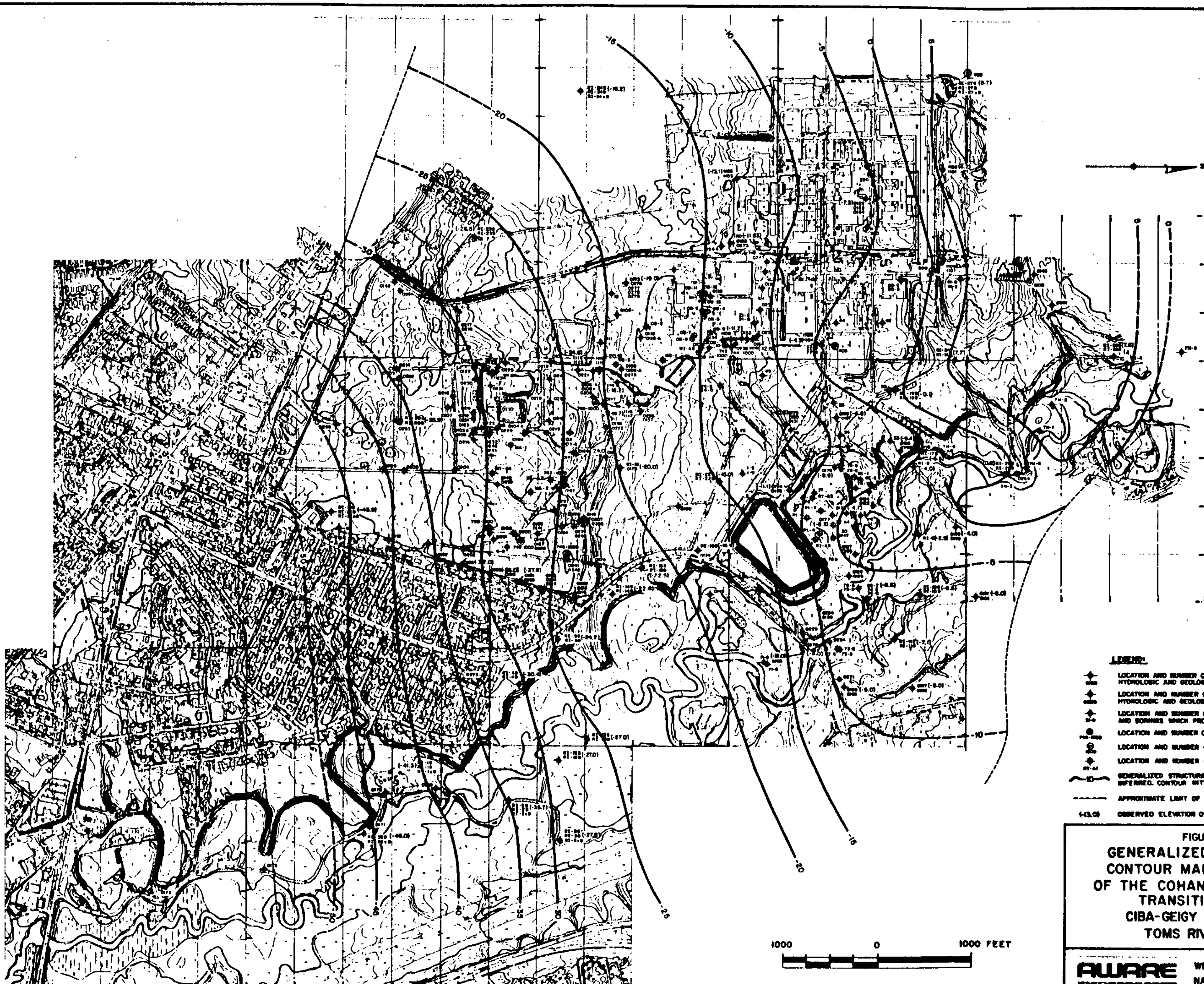
Cohansey/Kirkwood Transitional Unit

The Lower Cohansey Sand is conformably overlain by a unit herein termed the Cohansey/Kirkwood Transitional Unit. The Cohansey/Kirkwood Transitional Unit was encountered in 57 of the borings performed within the study area and was penetrated in 32 of the borings. Where penetrated, the unit ranged in thickness from 5.6 feet to 32 feet. Elevations ranged from +7.8 feet to -64.8 feet. The unit was typically described as follows:

> Dark gray to dark brown, yellow, or orange f SAND and SILT
> to f SAND, some Silt, micaceous, loose (soft to very soft)

The Cohansey/Kirkwood Transitional Unit is distinguished from the underlying Lower Cohansey Sand and the overlying Primary Cohansey Sand by its significantly finer-grained nature and typically, the abundance of mica. The Cohansey/Kirkwood Transitional Unit can also be distinguished from the adjacent units by a significant density contrast. For example, blow counts obtained during the Standard Penetration Test are typically in the range of 20 to 30 blows per six inches for the Cohansey/Kirkwood Transitional Unit. Blow counts in the Lower Cohansey Sand and the Primary Cohansey Sand, on the other hand, are typically in the range of 50 to 100 blows per six inches.

The generalized configuration of the upper surface of the Cohansey/Kirkwood Transitional Unit is depicted on Figure 4-20. Figure 4-21 is an isopachous map for the Cohansey/Kirkwood Transitional Unit developed through the conjunctive use of thickness data at individual boreholes and through subtraction of the top of the Lower Cohansey Sand (Figure 4-18) from the top of the Cohansey/Kirkwood Transitional Unit (Figure 4-20).



LEGEND:

- LOCATION AND NUMBER OF MONITORING WELLS WHICH PROVIDE HYDROLOGIC AND GEOLOGIC INFORMATION
- LOCATION AND NUMBER OF PIEZOMETERS WHICH PROVIDE HYDROLOGIC AND GEOLOGIC INFORMATION
- LOCATION AND NUMBER OF MONITORING WELLS, PIEZOMETERS, AND BORINGS WHICH PROVIDE ONLY GEOLOGIC INFORMATION
- LOCATION AND NUMBER OF PURGE WELLS
- LOCATION AND NUMBER OF PRODUCTION WELLS
- LOCATION AND NUMBER OF AUGER BORINGS
- GENERALIZED STRUCTURAL CONTOUR, IN FEET, DASHED WHERE INFERRED. CONTOUR INTERVAL IS FIVE FEET
- APPROXIMATE LIMIT OF MAPPED GEOLOGIC UNIT
- (-13.0) OBSERVED ELEVATION OF MAPPED GEOLOGIC UNIT, IN FEET

FIGURE 4-20

GENERALIZED STRUCTURAL CONTOUR MAP OF THE TOP OF THE COHANSEY / KIRKWOOD TRANSITIONAL UNIT

CIBA-GEIGY CORPORATION TOMS RIVER PLANT

AWARE INCORPORATED

WEST MILFORD, NEW JERSEY
NASHVILLE, TENNESSEE

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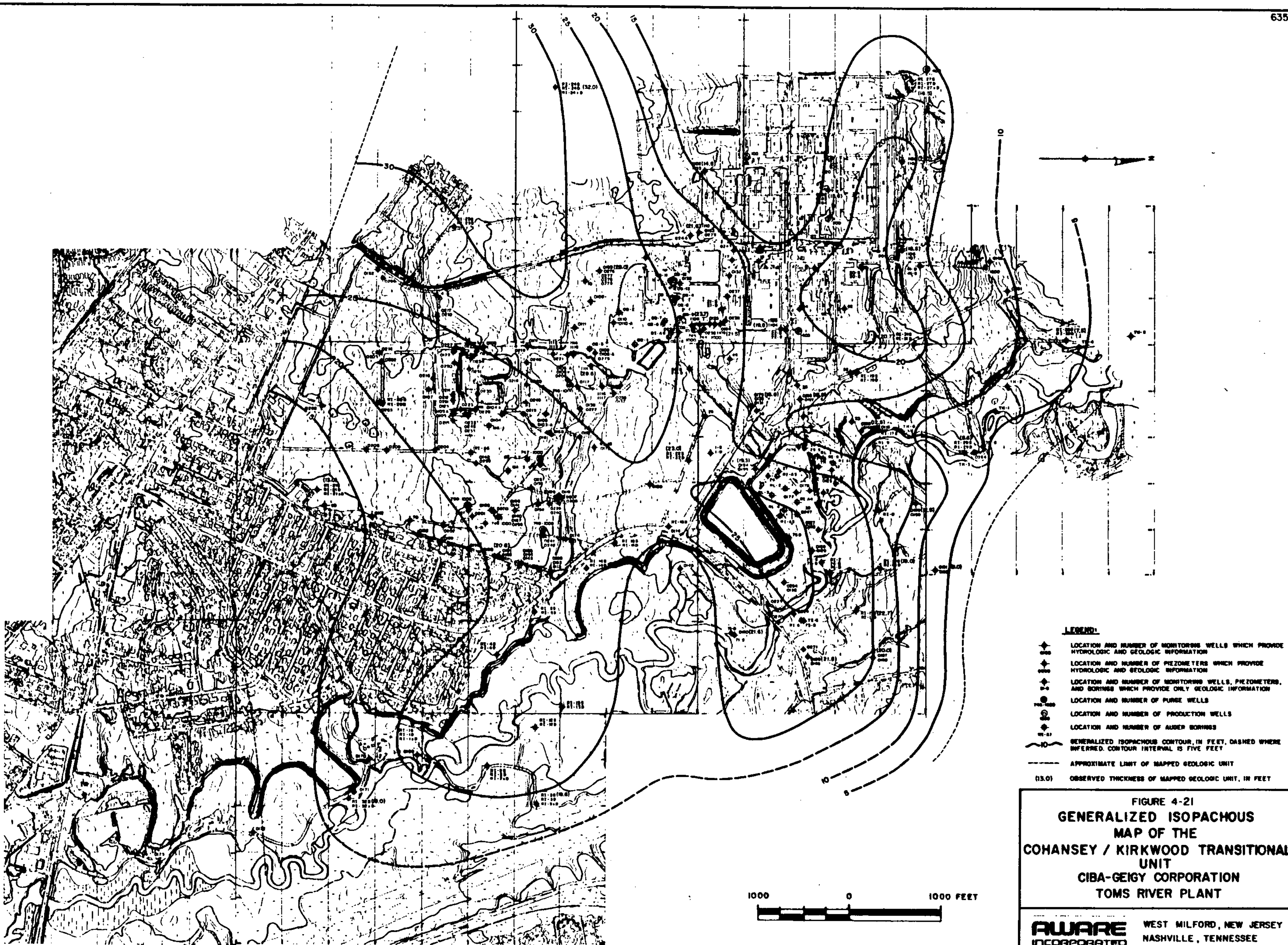

FIGURE 4-21
GENERALIZED ISOPACHOUS MAP OF THE COHANSEY / KIRKWOOD TRANSITIONAL UNIT
CIBA-GEIGY CORPORATION
TOMS RIVER PLANT

AWARE INCORPORATED
WEST MILFORD, NEW JERSEY
NASHVILLE, TENNESSEE

CIB 004 1906

Primary Cohansey Sand

The Cohansey/Kirkwood Transitional Unit is conformably overlain by a clean, well-sorted sand defined herein as the Primary Cohansey Sand. The Primary Cohansey Sand was encountered in all of the borings performed for this investigation with the exception of the shallow waste area auger borings. The unit was typically described as follows:

> Orange, yellow, tan, light gray, white, brown, and red-brown to purple-mottled, c-m-f SAND, trace to little Silt, trace f Gravel; well-sorted, slightly micaceous, medium dense to very dense.

The Primary Cohansey Sand can be distinguished from the underlying Cohansey/Kirkwood Transitional Unit and the overlying Yellow Clay/Black Organic Sand Unit (where present) on the basis of its coarser grain size, its well-sorted character, and the general absence of silt, clay, and organic matter. The contacts are also clearly distinguishable on natural gamma geophysical logs.

The Primary Cohansey Sand forms the most significant water-bearing zone beneath the area of investigation.

Yellow Clay/Black Organic Sand Unit

The Primary Cohansey Sand is conformably overlain by a unit herein termed the Yellow Clay/Black Organic Sand Unit. The Yellow Clay/Black Organic Sand Unit has been tentatively identified in 52 borings performed within the study area. Where penetrated, the unit ranged in thickness from 6.6 feet to 23 feet. The unit was typically described as follows:

> Yellow, tan, and dark gray to dark brown, laminated CLAY & SILT to Silty CLAY, soft to very soft, thinly interbedded with yellow, white or orange c SAND; grading downward to orange c-m-f SAND, little to trace Silt; grading to black, organic m-f SAND, little to trace Silt, with occasional peat or dark gray, organic CLAY & SILT at base.

The Yellow Clay/Black Organic Sand Unit is distinguished from the underlying Primary Cohansey Sand and the overlying Upper Cohansey Sand by its significantly finer-grained nature and, in part, by its significantly lower density. For example, blow counts obtained during the Standard Penetration Test are typically in the range of 5 to 10 blows per six inches for the clay member of the Yellow Clay/Black Organic Sand Unit. Blow counts in the Primary Cohansey Sand and the Upper Cohansey Sand are typically in the range of 50 to 100 blows per six inches. The organic sand member of the unit is distinguished by its significantly higher percentage of organic matter, including peat, and by its dark color. The intervening sand member is separated largely on the basis of its position between the clay and organic sand members of the unit.

The generalized configuration of the upper surface of the Yellow Clay/Black Organic Sand Unit is depicted on Figure 4-22. Figure 4-23 is an isopachous map for the upper clay member of the Yellow Clay/Black Organic Sand Unit developed through the conjunctive use of thickness data at individual

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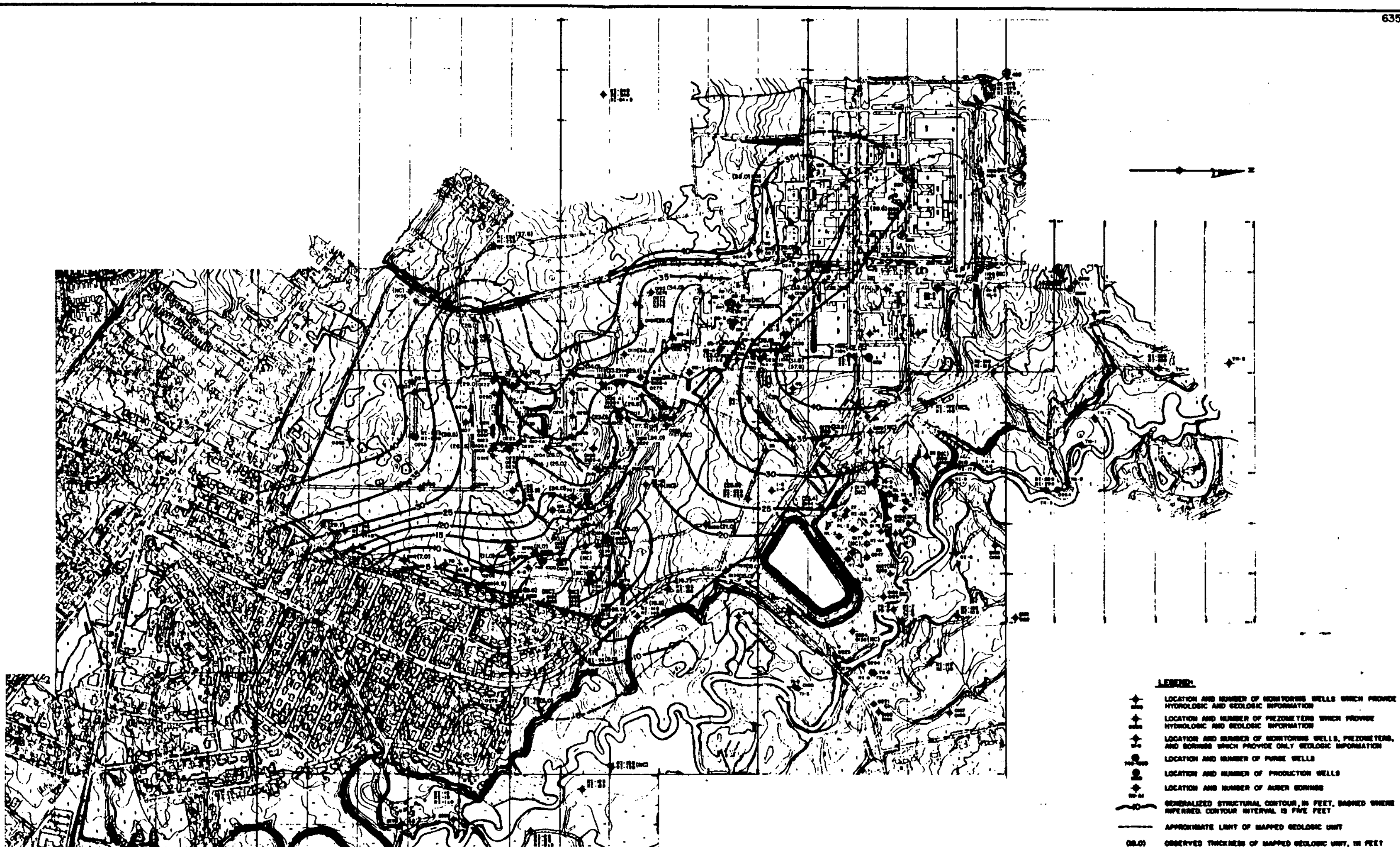
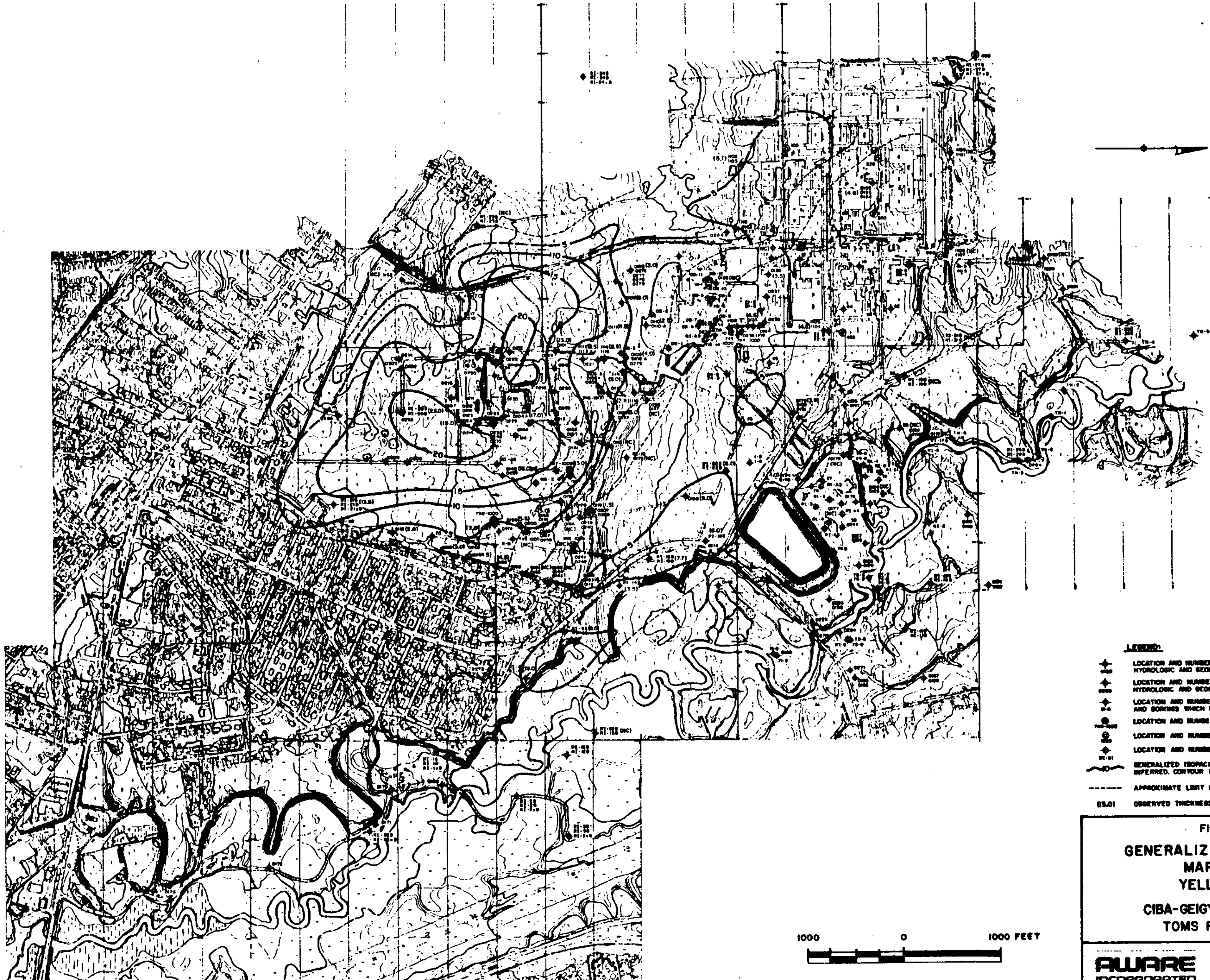


FIGURE 4-22
GENERALIZED STRUCTURAL CONTOUR MAP OF THE TOP OF THE YELLOW CLAY/BLACK ORGANIC SAND UNIT
CIBA-GEIGY CORPORATION
TOMS RIVER PLANT

AWARE INCORPORATED
WEST MILFORD, NEW JERSEY
NASHVILLE, TENNESSEE

CIB 004 1908



LEGEND:

- LOCATION AND NUMBER OF MONITORING WELLS WHICH PROVIDE HYDROLOGIC AND GEOLOGIC INFORMATION
- LOCATION AND NUMBER OF PIEZOMETERS WHICH PROVIDE HYDROLOGIC AND GEOLOGIC INFORMATION
- LOCATION AND NUMBER OF MONITORING WELLS, PIEZOMETERS, AND BORINGS WHICH PROVIDE ONLY GEOLOGIC INFORMATION
- LOCATION AND NUMBER OF PURGE WELLS
- LOCATION AND NUMBER OF PRODUCTION WELLS
- LOCATION AND NUMBER OF AUGER BORINGS
- GENERALIZED ISOPACHOUS CONTOUR, IN FEET, DASHED WHERE INFERRED. CONTOUR INTERVAL IS FIVE FEET
- APPROXIMATE LIMIT OF MAPPED GEOLOGIC UNIT
- (13.0) OBSERVED THICKNESS OF MAPPED GEOLOGIC UNIT, IN FEET

FIGURE 4-23

GENERALIZED ISOPACHOUS MAP OF THE YELLOW CLAY

CIBA-GEIGY CORPORATION TOMS RIVER PLANT

AWARE INCORPORATED

WEST MILFORD, NEW JERSEY
NASHVILLE, TENNESSEE

boreholes, interpretation of natural gamma geophysical logs, and through subtraction of the base of Yellow Clay/Black Organic Sand Unit (Figure 4-24) from the top of the Yellow Clay/Black Organic Sand Unit (Figure 4-22).

We have defined this seemingly diverse sequence of deposits as a single stratigraphic entity on the basis of its similarity to a facies sequence in the Cohansey recognized by Carter (1972, 1978). Carter described the organic member of the sequence as follows:

> "The compact brownish-black peat...overlies, with a well-defined sharp contact, the burrowed laminated sand and in places grades laterally into pods of peat-rich brownish-gray clay. Horizontal laminations can be traced from the peat to the clay.
>
> The peat can be divided into three units. The basal unit is sandy and contains sand lenses and poorly preserved roots and leaf fragments. The middle unit is nearly sand-free and contains many roots...and leaf fragments. The top unit consists of thin intercalated laminations of peat and yellowish-gray silt.
>
> The basal and top units are intensely burrowed. The burrows are filled with silt and fine sand.
>
> The lateral persistence and numerous roots suggest in situ deposition. Moreover, the silt and sand within the facies indicate flooding, which provided the sediment as well as a tolerable environment for the burrowers. These inferences, combined with palynological analyses which show that 63 percent of the taxa inhabit freshwater swamps..., suggest that the peat is a freshwater marsh deposit".

Carter also described a thinly laminated clay facies that:

> "...makes up sections that range from less than 30 cm to 1.5 m in thickness. It is continuous throughout a locality, although it may differ as much as a meter in thickness. The unit may include an interbedded sand, and it grades laterally into, as well as sharply caps, the peat.
>
> The best defined section consists of pale-reddish-brown and blue-gray laminated clay that grades upward into silty and/or sandy clay containing peat fragments. Lenses of silt and fine sand are scattered throughout the clay; at the top of the clay there are silt-filled burrows. In sharp contact is an overlying intensely bioturbated silty sand, which commonly is about 30 cm thick but pinches out in places; this bed contains peat fragments, poorly preserved burrows, remnant cross-bedding, and up to 5 percent heavy minerals. The sand grades upward into a yellowish-orange laminated clay that is, in general, similar to the basal clay.

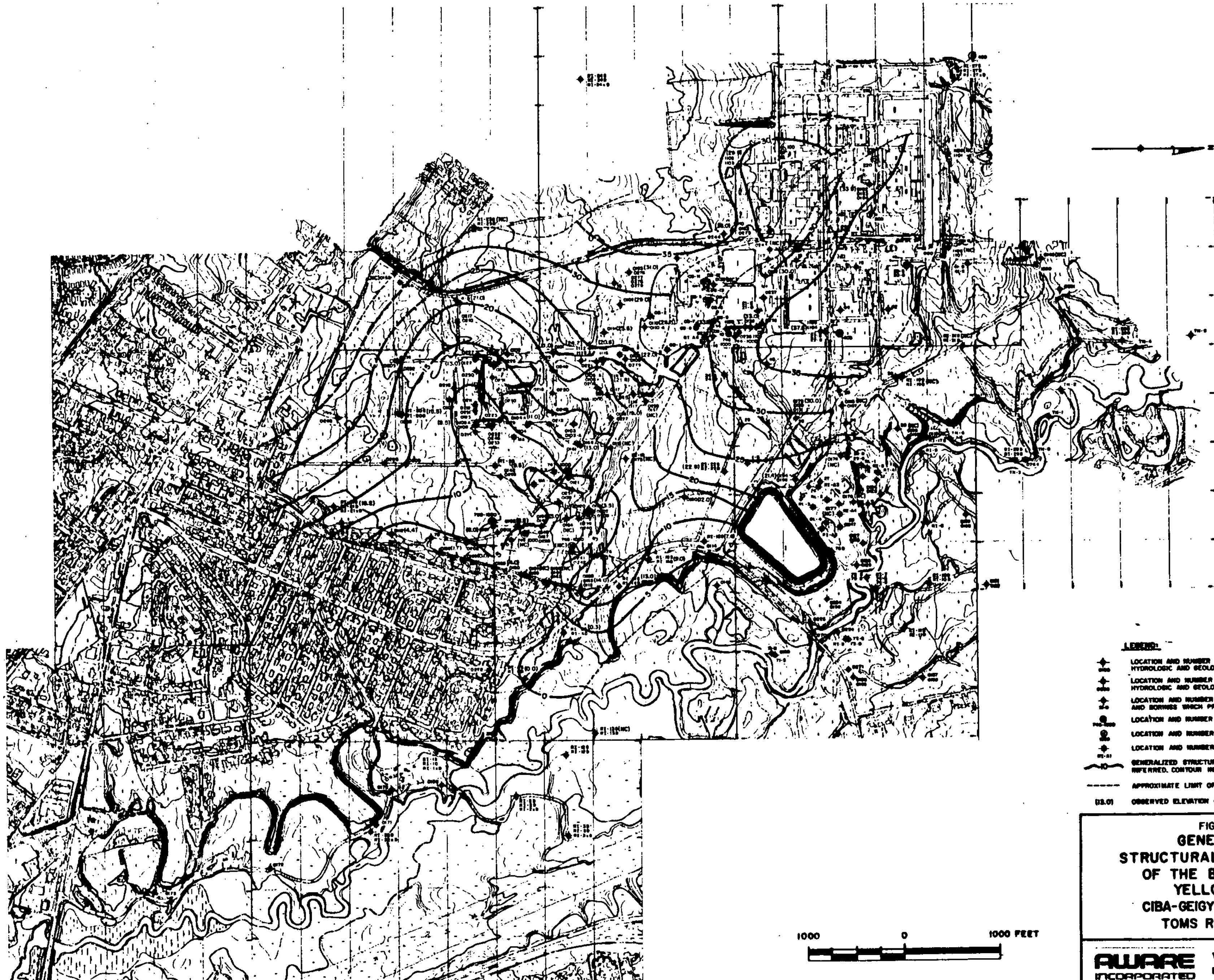


FIGURE 4-24
GENERALIZED STRUCTURAL CONTOUR MAP OF THE BASE OF THE YELLOW CLAY
CIBA-GEIGY CORPORATION
TOMS RIVER PLANT

AWARE INCORPORATED
WEST MILFORD, NEW JERSEY
NASHVILLE, TENNESSEE

Carter interpreted this sequence as follows:

> "The peat was deposited in a freshwater marsh in the lee of the eolian barrier dunes away from intense salt spray. Close to the freshwater marsh lies the barrier fringing salt marsh which acted as a baffle to trap floccules of clay-size particles and/or to retain fecal pellets. Thus the facies in [this sequence are] simply the result of a seaward-migrating barrier [island complex]."

The Yellow Clay/Black Organic Sand Unit is recognizable across a significant percentage of the study area as a distinct lithostratigraphic unit. However, not all members of the sequence are present continuously across the area of investigation. For example, Figures 4-22, 4-23, and 4-24 suggest the presence of a nearly linear gap in the top of the Yellow Clay/Black Organic Sand Unit in the vicinity of the former landfill and the Cardinal Drive boundary of the Toms River Plant. This feature represents an area where the upper clay member of the sequence is absent. Examination of boring logs in the vicinity of the feature indicate a lateral gradation from substantial thicknesses of clay to interbedded clay and sand and finally to sand alone. Natural gamma logs for wells and borings in this area clearly indicate a "clay-rich" unit thinning towards, then disappearing within the apparent clay gap (Figure 4-25). It is also conceivable that some of the clay units that have been interpreted as correlative could represent discontinuous lenses. However, this is considered unlikely except near the fringes of the area mapped.

Upper Cohansey Sand

The Yellow Clay/Black Organic Sand Unit is conformably overlain by a clean, well-sorted sand defined herein as the Upper Cohansey Sand. The Upper Cohansey Sand was encountered in virtually all of the borings performed for this investigation. The unit was typically described as follows:

> Orange, brown, yellow, tan, and light gray, c-m-f SAND, trace to little Silt, trace f Gravel; well-sorted, medium dense to very dense.

The Upper Cohansey Sand can be distinguished from the underlying Yellow Clay/Black Organic Sand Unit on the basis of its coarser grain size, its well-sorted character, and the general absence of silt, clay, and organic matter. The contact is also clearly distinguishable on natural gamma geophysical logs (e.g., Figure 4-25).

The Upper Cohansey Sand as defined herein undoubtedly includes sands of the Pennsauken and Cape May Formations. From the standpoint of the remedial investigation, the differences between the various sands are considered to be of little or no consequence. Moreover, from a hydrologic standpoint there is clearly no need to differentiate among these sands.

The Upper Cohansey Sand forms a shallow water-bearing zone beneath a limited area of the site. Within this area, however, the unit may play an important role in the migration of contaminants to the Primary Cohansey.

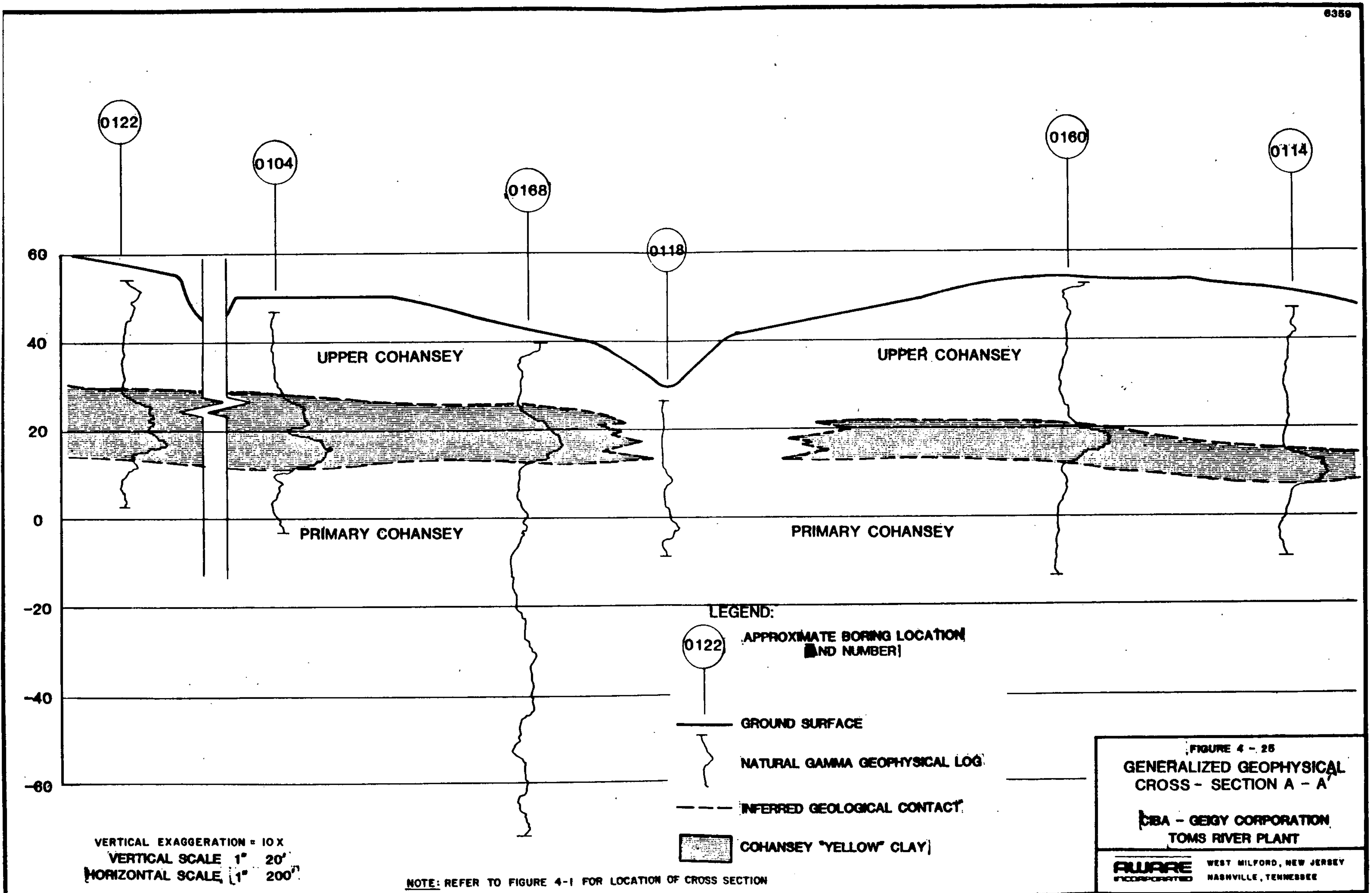


FIGURE 4 - 25
GENERALIZED GEOPHYSICAL CROSS - SECTION A - A'
CIBA - GEIGY CORPORATION
TOMS RIVER PLANT

CIB 004 1913

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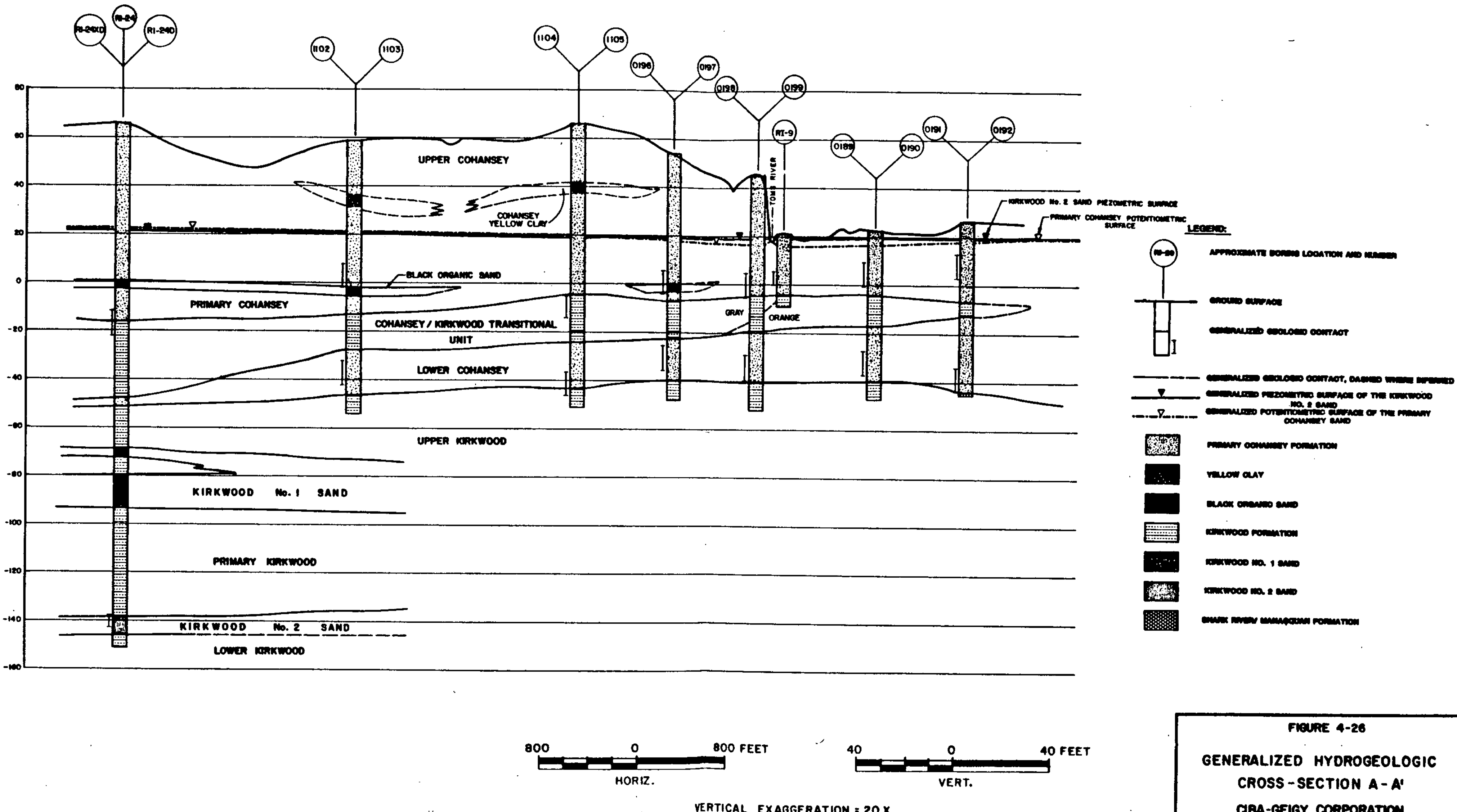


NOTE: REFER TO FIGURE 4-1 FOR LOCATION OF CROSS SECTION

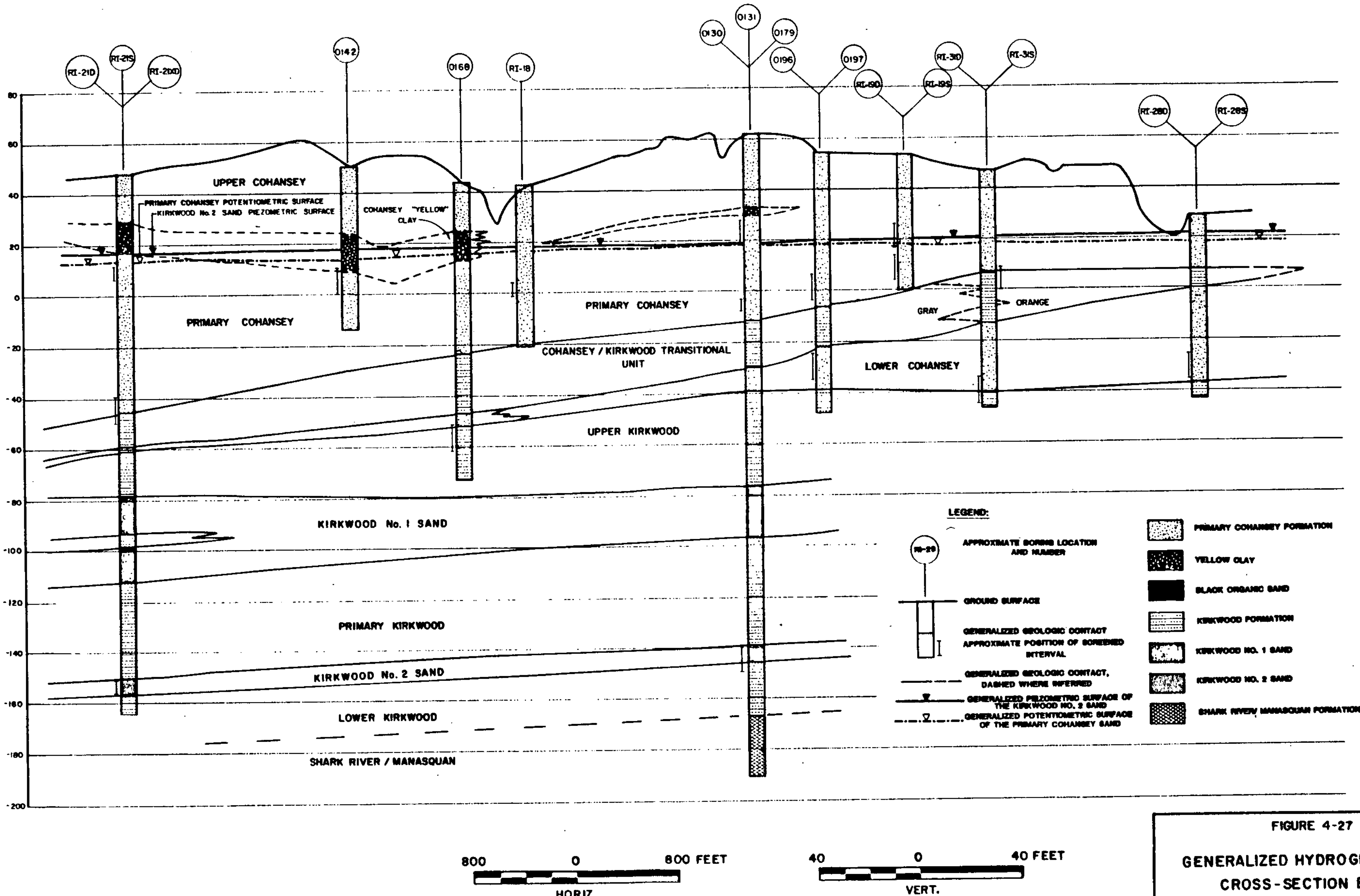
FIGURE 4-26

GENERALIZED HYDROGEOLOGIC CROSS-SECTION A-A'

CIBA-GEIGY CORPORATION
TOMS RIVER PLANT

GERAGHTY & MILLER INCORPORATED — WEST MILFORD, NEW JERSEY; NASHVILLE, TENNESSEE

CIB 004 1914



VERTICAL EXAGGERATION = 20X

NOTE: REFER TO FIGURE 4-1 FOR LOCATION OF CROSS SECTION

FIGURE 4-27

GENERALIZED HYDROGEOLOGIC CROSS-SECTION B-B'

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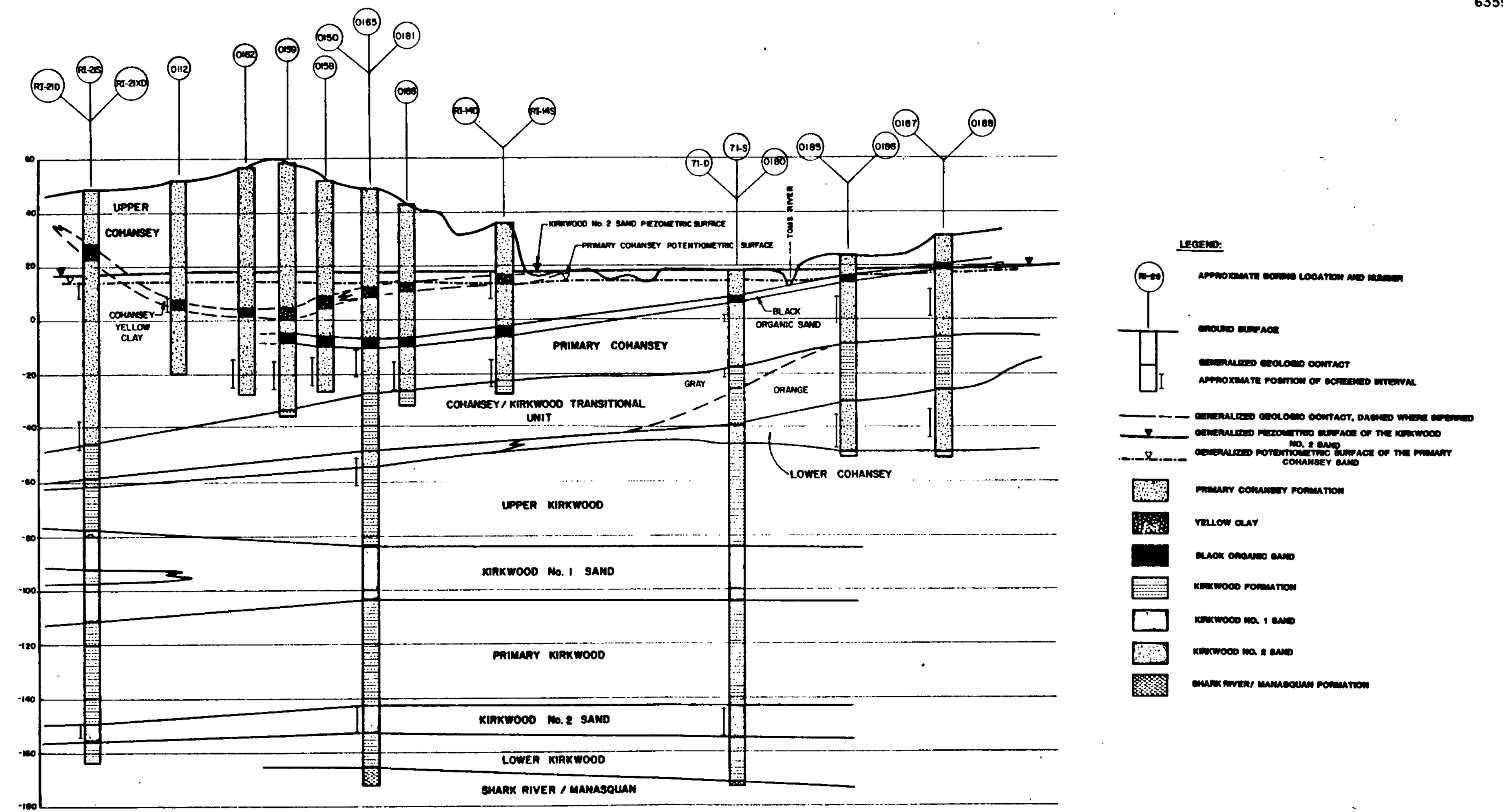
6359



800 0 800 FEET
HORIZ.

40 0 40 FEET
VERT.

VERTICAL EXAGGERATION = 20 X

NOTE: REFER TO FIGURE 4-1 FOR LOCATION OF CROSS SECTION

FIGURE 4-28

GENERALIZED HYDROGEOLOGIC CROSS-SECTION C - C'

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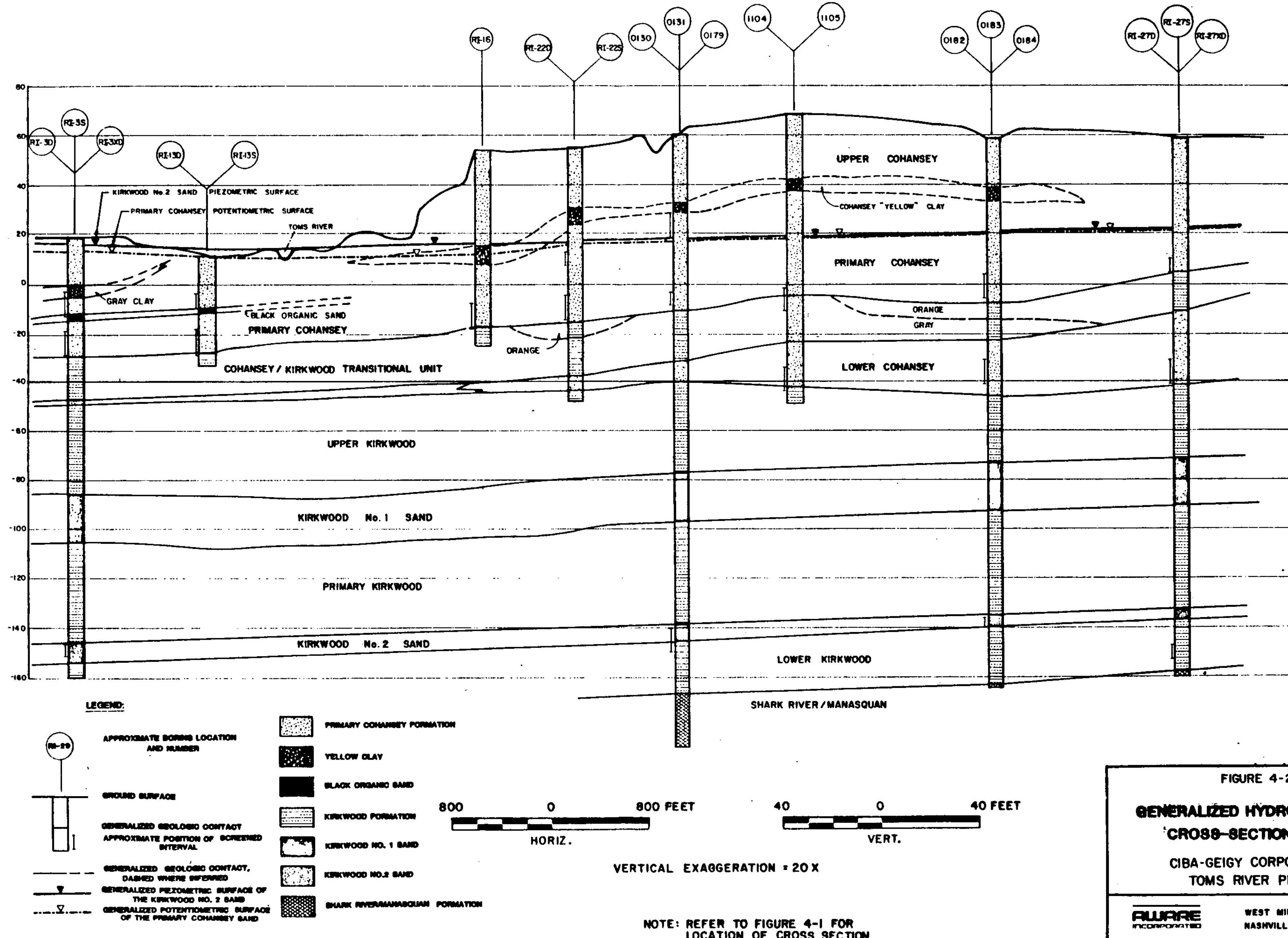

NOTE: REFER TO FIGURE 4-1 FOR LOCATION OF CROSS SECTION

FIGURE 4-29

GENERALIZED HYDROGEOLOGIC CROSS-SECTION D – D'

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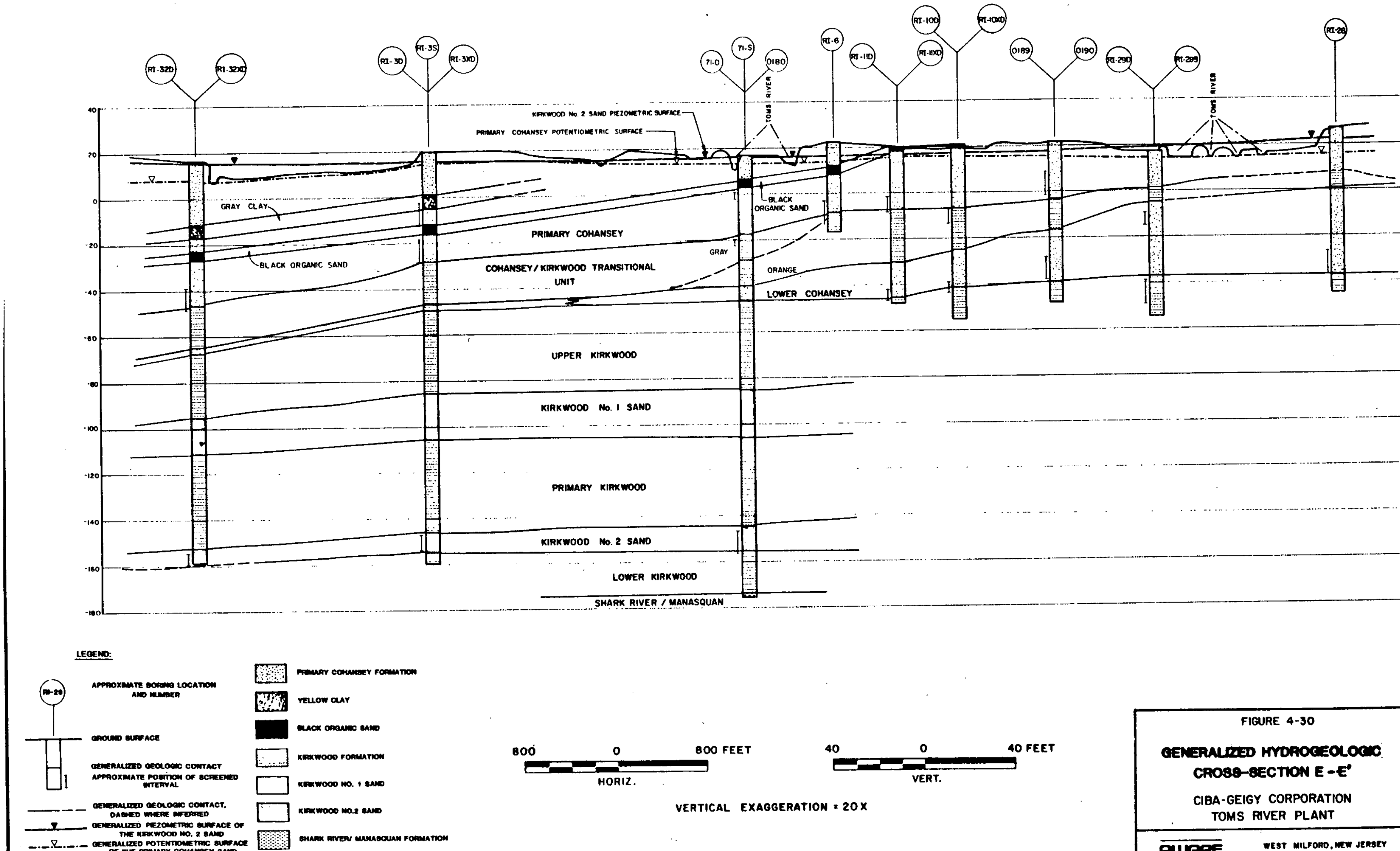
NASHVILLE, TENNESSEE

6359



NOTE: REFER TO FIGURE 4-1 FOR LOCATION OF CROSS SECTION

FIGURE 4-30

GENERALIZED HYDROGEOLOGIC CROSS-SECTION E-E'

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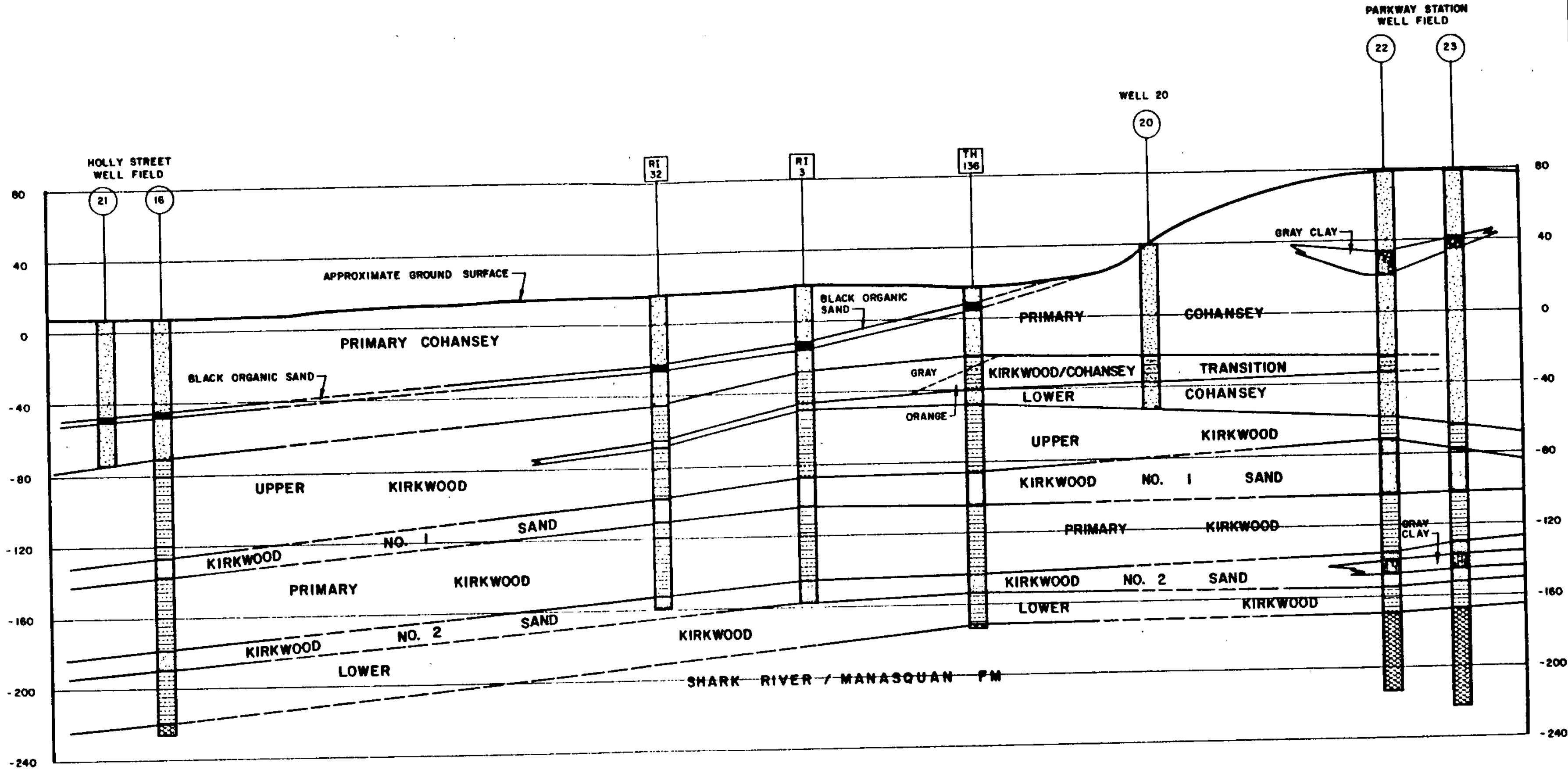

NOT TO SCALE

EXPLANATION

RI 32 — APPROXIMATE LOCATION OF TEST BORING

20 — APPROXIMATE LOCATION OF TOMS RIVER WATER COMPANY PRODUCTION OR TEST WELL. ELEVATIONS ARE APPROXIMATE. STRATIGRAPHY INTERPRETED FROM DRILLER'S LOGS.

—— INFERRED STRATIGRAPHIC CONTACT. DASHED CONTACT INDICATES A HIGHER LEVEL OF INFERENCE.

FIGURE 4 - 31

GENERALIZED STRATIGRAPHIC CROSS-SECTION - HOLLY STREET WELL FIELD TO PARKWAY STATION WELL FIELD

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4.3.3 Hydraulic Conductivity Determinations

The hydraulic conductivities of the major aquifers and aquitards present beneath the site represent perhaps the most critical physical parameters that must be determined during a remedial investigation. Given sufficient continuity of the strata and known hydraulic gradients, it is the hydraulic conductivity that will control the migration pathways for contaminants as well as the volumetric rates of groundwater flow. Moreover, determination of both aquifer and aquitard hydraulic conductivity is essential for the assessment of hydraulically-based remedial measures such as groundwater recovery systems and induced hydraulic barriers.

In this section, the results of several different hydraulic conductivity testing programs are described. These methods include laboratory testing of "undisturbed" Shelby tube samples, as well as several methods of direct, in situ field testing. The latter include variable head recovery tests of individual monitoring wells, a constant-head aquifer test conducted on purge well 747-1000, and a comprehensive aquifer/aquitard pumping test that enabled field determination of the hydraulic conductivity of the Upper Kirkwood aquitard. The findings of the various hydraulic conductivity testing programs are described below.

<u>Laboratory Testing of Undisturbed Samples</u>

During the course of the remedial investigation 12 "undisturbed" Shelby tube samples were collected from the Kirkwood formation. Ten of these samples were subjected to a number of soil laboratory tests including vertical hydraulic conductivity. The tests performed on the samples included:

- Grain size distribution
- Porosity
- Density
- Atterberg Limits
- Consolidation
- Vertical hydraulic conductivity

The results of the general laboratory testing are submitted in Table 4-11. The laboratory testing was subcontracted to Woodward-Clyde Consultants of Clifton, New Jersey. The laboratory reports and grain-size distribution curves are presented in Volume IV of this document.

The vertical hydraulic conductivity tests were performed employing a triaxial cell-based constant volume, variable head permeameter. In a triaxial cell the soil specimen is enclosed in a flexible membrane and is placed under a confining pressure. The combination of the flexible membrane and the confining pressure minimizes the opportunity for preferential leakage along the sides of the soil specimen. The confining pressure can also be varied to simulate in-situ conditions. The results of the laboratory testing are summarized on Table 4-12.

Of the ten "undisturbed" samples submitted for laboratory testing, one sample was from the Cohansey/Kirkwood Transitional Unit, six samples were from the Upper Kirkwood, and three were samples of the Primary Kirkwood.

TABLE 4-11

SUMMARY OF LABORATORY SOILS DATA

ring/Well Number	Sample Number	Depth (feet)	Atterburg Limits LL (%)	PL (%)	PI (%)	-200 Sieve (%)	(lb/ft.^{3})
'44-0179	S-60	165.5	Non-plastic			42.1	120.2
744-0179	S-64	185.5	Estimated		5-10	95.3	119.9
'44-0180	S-38	81.0	Estimated		<3	19.2	121.3
'44-0181	S-38	85.5	Non-plastic			25.3	121.4
744-0181	S-59	188.0	Estimated		<3	69.5	120.9

TABLE 4-12

SUMMARY OF LABORATORY HYDRAULIC CONDUCTIVITY DATA

Boring Number	Sample Number	Geologic Unit	Hydraulic Conductivity, in cm/sec
744-0179	SS-60	Primary Kirkwood	2.5×10^{-5}
744-0179	SS-64	Primary Kirkwood	1.6×10^{-7}
744-0180	SS-38	Upper Kirkwood	1.8×10^{-4}
744-0181	SS-38	Coh/Kirkwood Trans	1.6×10^{-4}
744-0181	SS-59	Primary Kirkwood	8.1×10^{-6}
744-0276	S-1	Upper Kirkwood	1.2×10^{-5}
744-0277	S-2	Upper Kirkwood	4.8×10^{-8}
744-0277	S-3	Upper Kirkwood	2.8×10^{-5}
744-0277	S-4	Upper Kirkwood	3.7×10^{-5}
744-0278	S-5	Upper Kirkwood	1.4×10^{-5}

The single sample of the transitional unit indicated an hydraulic conductivity of 1.6 x 10^{-4} cm/sec. The hydraulic conductivity of the Upper Kirkwood ranged from 4.8 x 10^{-8} cm/sec to 1.4 x 10^{-4} cm/sec, with a geometric mean of 1.0 x 10^{-5} cm/sec. If we exclude the clearly unrepresentative value of 4.8 x 10^{-8} cm/sec, the geometric mean is 3.2 x 10^{-5} cm/sec.

It appears that one unrepresentative soil specimen had an unusually high clay content which is not representative of the aquitard. Moreover, it is not likely that the clay zone encountered in this particular sample is continuous to a degree which would materially affect the overall effective hydraulic conductivity of the aquitard.

The hydraulic conductivity of the Primary Kirkwood ranged from 1.6 x 10^{-7} cm/sec to 2.5 x 10^{-5} cm/sec. The geometric mean of the three tests is 3.2 x 10^{-6} cm/sec. The apparently lower hydraulic conductivity of the Primary Kirkwood suggested by these tests is consistent with the lithology observed during the remedial investigation. The estimated effective vertical hydraulic conductivity would be on the order of 1.0 x 10^{-5} cm/sec.

Variable Head Recovery Tests

In order to determine the in-place lateral hydraulic conductivity of the saturated materials, variable head recovery tests were performed on a number of the existing and newly installed monitoring wells. The field tests involve rapidly lowering the water level in the well and measuring the change in head with respect to time as the monitoring well is allowed to recover.

The field methodology utilized an In Situ, Inc. Hermit model automatic data logger and pressure transducer system to measure water level changes. The Hermit data logger permitted measurement of water levels at frequent time intervals, much more frequently than could have been acheived manually. The recovery tests were conducted as follows:

The static water level in the monitoring well was measured and recorded.

The pressure transducer was placed in the well, followed by a standard PVC or Teflon bailer. Water level measurements were continued until the water level had returned to static conditions following introduction of the transducer and bailer.

Once static conditions were re-established, the bailer was rapidly removed from the water column, thus creating a virtually instantaneous decline of the water level in the well. Coincident with the withdrawal of the bailer, automatic logging of the water levels was initiated using the Hermit data logger.

The water level measurements were typically continued until water levels had recovered to within 10% of the original static level (90% recovery). In several cases, however, the tests were concluded prior to 90% recovery. Where the recorded recovery was less than 90%, we have included the results only if they appear to be consistent with the theory for such tests.

It is assumed that the rate of inflow to the well screen after pumping, at any time, is proportional to the hydraulic conductivity (k) and to the unrecovered head distance. A semi-log plot of the unrecovered head distance or head ratio (h_t/h_o) versus time (t) indicates an exponential decline in the recovery rate over time.

The following equation is used to calculate the in situ hydraulic conductivity of the saturated materials at the screened interval of the piezometer (Cedergren, 1977).

$$k = \frac{r^2}{2L(t_2 - t_1)} \ln(L/R) \times \ln(h_1 / h_2)$$

Where:

L = Screen length, in cm
r = Screen radius, in cm
R = Gravel pack radius, in cm
t1 = Time interval corresponding to h_1, in sec
t2 = Time interval corresponding to h_2, in sec
h1 = Head ratio at time t_1, dimensionless
h2 = Head ratio at time t_2, dimensionless
k = Hydraulic conductivity, in cm/sec

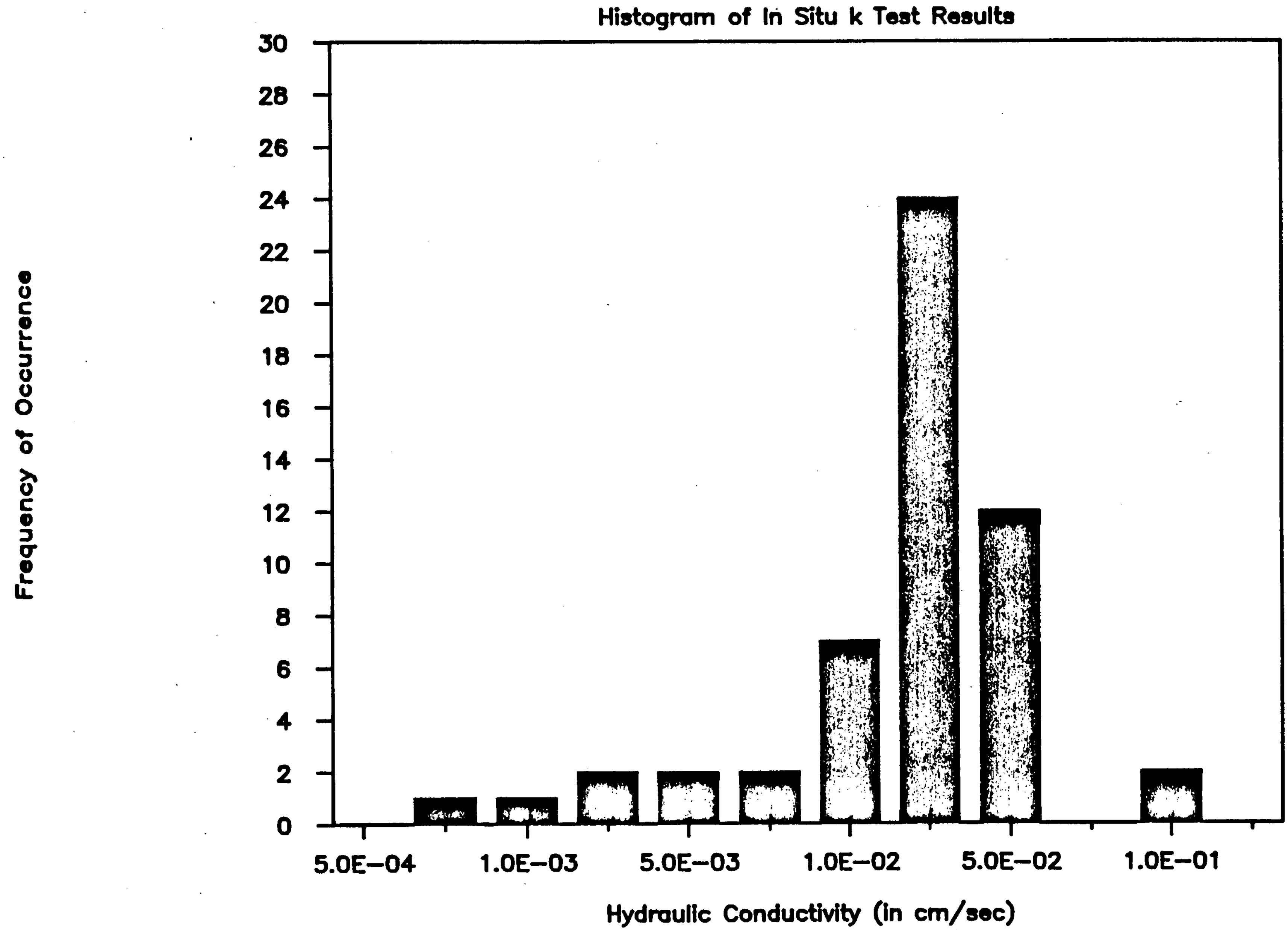
The results of the in situ recovery tests are summarized on Table 4-13. The calculations and graphical analyses for each monitoring well tested are presented in Volume IV of this document.

The arithmetic mean hydraulic conductivity of 53 in situ tests of the Cohansey Formation is 2.0×10^{-2} cm/sec. The geometric mean, a measure of central tendency that is less sensitive to infrequent high values in the data set, is 1.5×10^{-2} cm/sec. The minimum observed hydraulic conductivity was 6.9×10^{-4} cm/sec in monitoring well 744-0183; the highest observed value was 1.0×10^{-1} cm/sec in monitoring well 744-0112. The frequency distribution of in situ test results is depicted on Figure 4-32.

Constant-Discharge Aquifer Test

In January of 1985, an aquifer test was performed at purge well 747-1000. Well 747-1000 is one of five purge wells comprising the Cardinal Drive groundwater recovery system. The pumping well was equipped with a diesel engine-driven turbine pump. Pumping of the well was subcontracted to W. C. Services of Woodbury, New Jersey. Discharging groundwater was directed away from the aquifer test site in order to minimize any recharge of water back to the Cohansey Sand aquifer within the cone of influence of the aquifer test. Drawdowns were measured in a number of existing wells in the vicinity of well 747-1000. These wells included 744-0121, 744-0161, 744-0139, 744-0138, 744-0175, and 744-0118. Wells 744-0121 and 744-0161 lie closest to the pumping well and emphasis was placed on water level measurements in these wells during the aquifer test. Water levels were manually collected employing a weighted tape. Well 747-1000 was pumped at a constant rate of 115 gallons per minute for a period of 4300 minutes. The test was supervised and all drawdown measurements were taken by hydrogeologists from AWARE.

FIGURE 4–32



CIB 004 1925

TABLE 4-13

SUMMARY OF IN SITU HYDRAULIC CONDUCTIVTY DATA

WELL NUMBER	GEOLOGIC UNIT	HYDRAULIC CONDUCTIVITY (in cm/sec)
744-0101	COHANSEY	2.1E-02
744-0102	COHANSEY	3.1E-02
744-0103	COHANSEY	1.2E-02
744-0104	COHANSEY	9.6E-04
744-0105	COHANSEY	1.0E-02
744-0107	COHANSEY	3.1E-02
744-0108	COHANSEY	9.3E-02
744-0109	COHANSEY	4.3E-03
744-0110	COHANSEY	1.5E-02
744-0111	COHANSEY	4.5E-03
744-0112	COHANSEY	1.0E-01
744-0113	COHANSEY	1.8E-02
744-0114	COHANSEY	1.0E-02
744-0117	COHANSEY	1.5E-02
744-0118	COHANSEY	1.4E-02
744-0119	COHANSEY	6.6E-03
744-0120	COHANSEY	2.0E-02
744-0124	COHANSEY	3.1E-02
744-0125	COHANSEY	4.1E-02
744-0127	COHANSEY	3.6E-02
744-0129	COHANSEY	3.3E-02
744-0132	COHANSEY	1.8E-02
744-0133	COHANSEY	2.3E-02
744-0134	COHANSEY	6.0E-03
744-0135	COHANSEY	2.4E-02
744-0136	COHANSEY	1.7E-02
744-0137	COHANSEY	1.3E-02
744-0139	COHANSEY	8.5E-03
744-0140	COHANSEY	1.1E-03
744-0141	COHANSEY	1.0E-02
744-0142	COHANSEY	2.3E-03
744-0144	COHANSEY	2.1E-02
744-0146	COHANSEY	8.6E-03
744-0152	COHANSEY	1.5E-02
744-0153	COHANSEY	2.1E-02
744-0154	COHANSEY	1.9E-02
744-0155	COHANSEY	1.1E-02
744-0156	COHANSEY	3.2E-02
744-0157	COHANSEY	4.4E-02
744-0158	COHANSEY	8.8E-03

TABLE 4-13, continued

SUMMARY OF IN SITU HYDRAULIC CONDUCTIVITY DATA

WELL NUMBER	GEOLOGIC UNIT	HYDRAULIC CONDUCTIVITY (in cm/sec)
744-0159	COHANSEY	3.9E-02
744-0160	COHANSEY	1.2E-02
744-0161	COHANSEY	2.6E-02
744-0162	COHANSEY	1.5E-02
744-0163	COHANSEY	3.6E-02
744-0166	COHANSEY	3.2E-02
744-0169	COHANSEY	1.6E-02
744-0171	COHANSEY	1.3E-02
744-0172	COHANSEY	2.4E-02
744-0173	COHANSEY	2.4E-02
744-0183	COHANSEY	6.9E-04
744-0184	COHANSEY	8.7E-03
744-0193	COHANSEY	1.2E-02
744-0165	UPPER KIRKWOOD	4.0E-03
744-0167	UPPER KIRKWOOD	2.4E-03
744-0168	UPPER KIRKWOOD	5.4E-03
744-0276	UPPER KIRKWOOD	2.2E-05
744-0277	UPPER KIRKWOOD	1.4E-03
744-0278	UPPER KIRKWOOD	2.2E-05
744-1109	KIRKWOOD #1 SAND	7.3E-03
744-1110	KIRKWOOD #1 SAND	2.5E-03
744-0179	KIKRWOOD #2 SAND	4.1E-03
744-0180	KIKRWOOD #2 SAND	5.0E-03
744-0181	KIKRWOOD #2 SAND	1.1E-02

SUMMARY STATISTICS FOR THE COHANSEY FORMATION

ARITHMETIC MEAN = 2.1E-02 CM/SEC

GEOMETRIC MEAN = 1.5E-02 CM/SEC

MAXIMUM = 1.0E-01 CM/SEC

MINIMUM = 6.9E-04 CM/SEC

Throughout the majority of the Ciba-Geigy site, the Primary Cohansey Sand aquifer occurs under unconfined or water table conditions. However, in the vicinity of well 747-1000, the yellow clay unit separating the Upper Cohansey from the Primary Cohansey is situated slightly below the groundwater table. As a result, the Primary Cohansey aquifer in this area behaves as a semi-confined aquifer provided that drawdowns are not deeper than the yellow clay unit itself. The semi-confined behavior of the Primary Cohansey aquifer in this area is evident in the time-drawdown graphs for wells 0121 and 0161 presented as Figures 4-33 and 4-34.

The fact that the Primary Cohansey Sand aquifer in this area behaves as a semi-confined aquifer causes drawdown from the pumping test to propagate radially outward from the pumping well quite rapidly, in keeping with the low storativity of a semi-confined aquifer. As a result, observation well response delay becomes a significant factor in analysis of the aquifer test results. In an unconfined or water table aquifer, observation response delay would not be a significant factor (Black and Kipp, 1977).

A slug test was performed on well 744-0121 to determine the "Well Response Factor". The "Well Response Time" was found to be six seconds. The Well Response Time is the time required for water levels in the well to recover to within 37 percent of the original static water levels. The "Well Response Factor" can be calculated from the Well Response Time and aquifer transmissivity, aquifer storativity, and the radial distance from the pumping well to the observation well. Employing typical aquifer properties and the radial distances from the monitoring wells to the pumping well, a well response factor of approximately 10 is found to be appropriate for wells 744-0121 and 744-0161.

Leaky artesian type curves (modified after Black and Kipp, 1977) for the effect of observation well response delay have been matched to the field data. Values of transmissivity, hydraulic conductivity, and storativity have been calculated as indicated in Figures 4-33 and 4-34 . A fair degree of conformance in the aquifer properties calculated from the time drawdown graphs for wells 744-0121 and 744-0161 is observed. Transmissivity was seen to vary from 60,000 to 94,000 gallons per day per foot, corresponding to aquifer hydraulic conductivities of 1,700 to 2,700 gallons per day per square foot. (9.4×10^{-2} to 1.2×10^{-1} cm/sec). Storativity varied from 2×10^{-5} to 1.4×10^{-4}. The results of this aquifer test are considered to be approximate due to the combined effects of aquitard storativity and leakage and observation well response delay.

Aquitard Testing

Estimation of the vertical hydraulic conductivity of an aquitard is in many respects a more difficult technical challenge than estimating the hydraulic conductivity or transmissivity of an aquifer. Traditionally, hydrogeologic studies have focused on aquifer properties as part of the water supply studies. In the last ten years, as attention has shifted more toward groundwater contamination, more techniques of aquitard evaluation have developed. There are a number of techniques applicable to aquitard hydraulic conductivity evaluation. However, no one technique is superior in all applications. Each technique has its own inherent advantages and disadvantages. Consequently, it was decided to undertake a comprehensive, multifaceted approach to evaluation of the Kirkwood

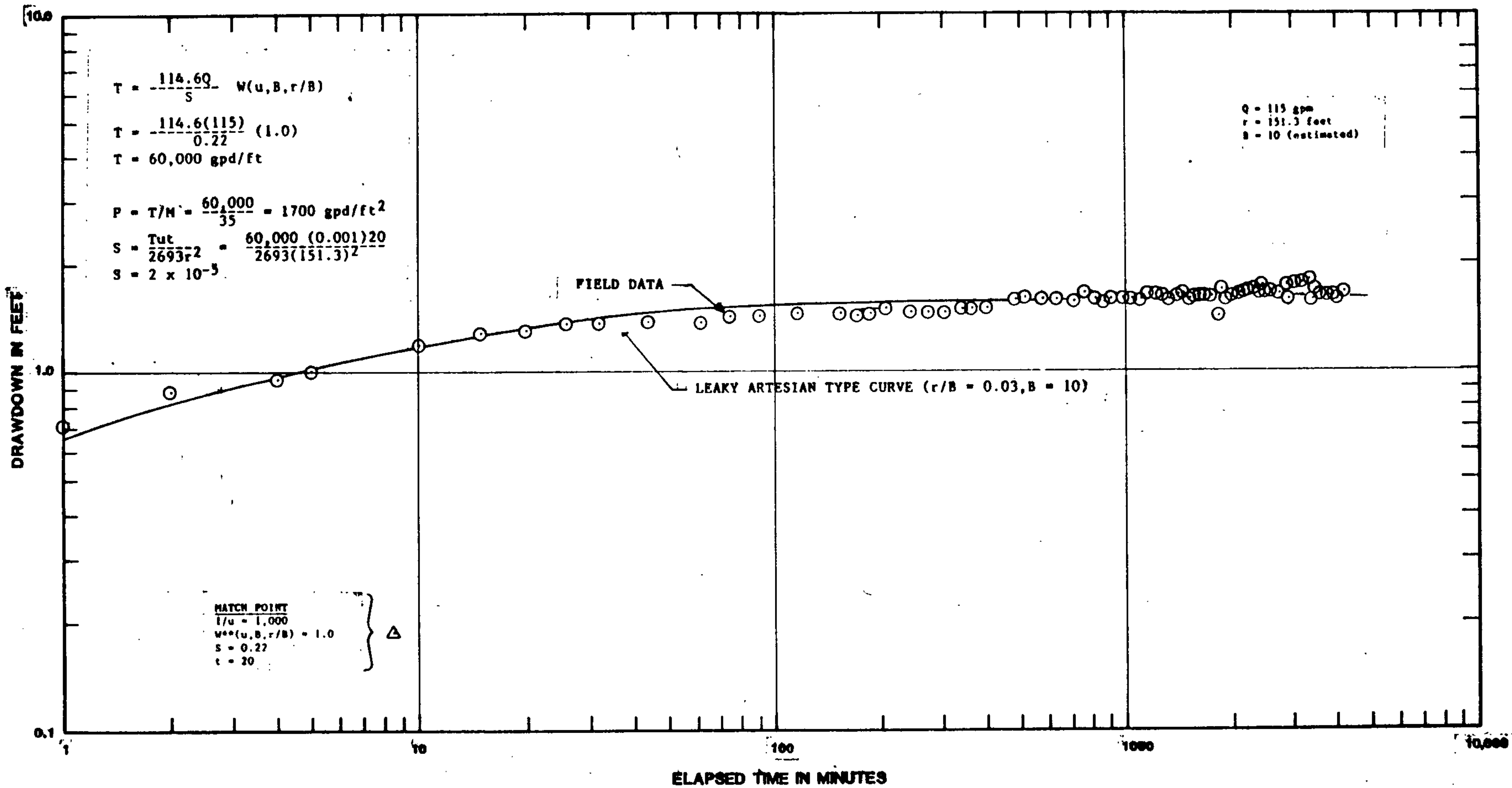


FIGURE 4 - 53

TIME - DRAWDOWN GRAPH
FOR WELL NO. 0121
AQUIFER TEST - WELL NO. 747-1000

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WEST MILFORD, NEW JERSEY
NASHVILLE, TENNESSEE

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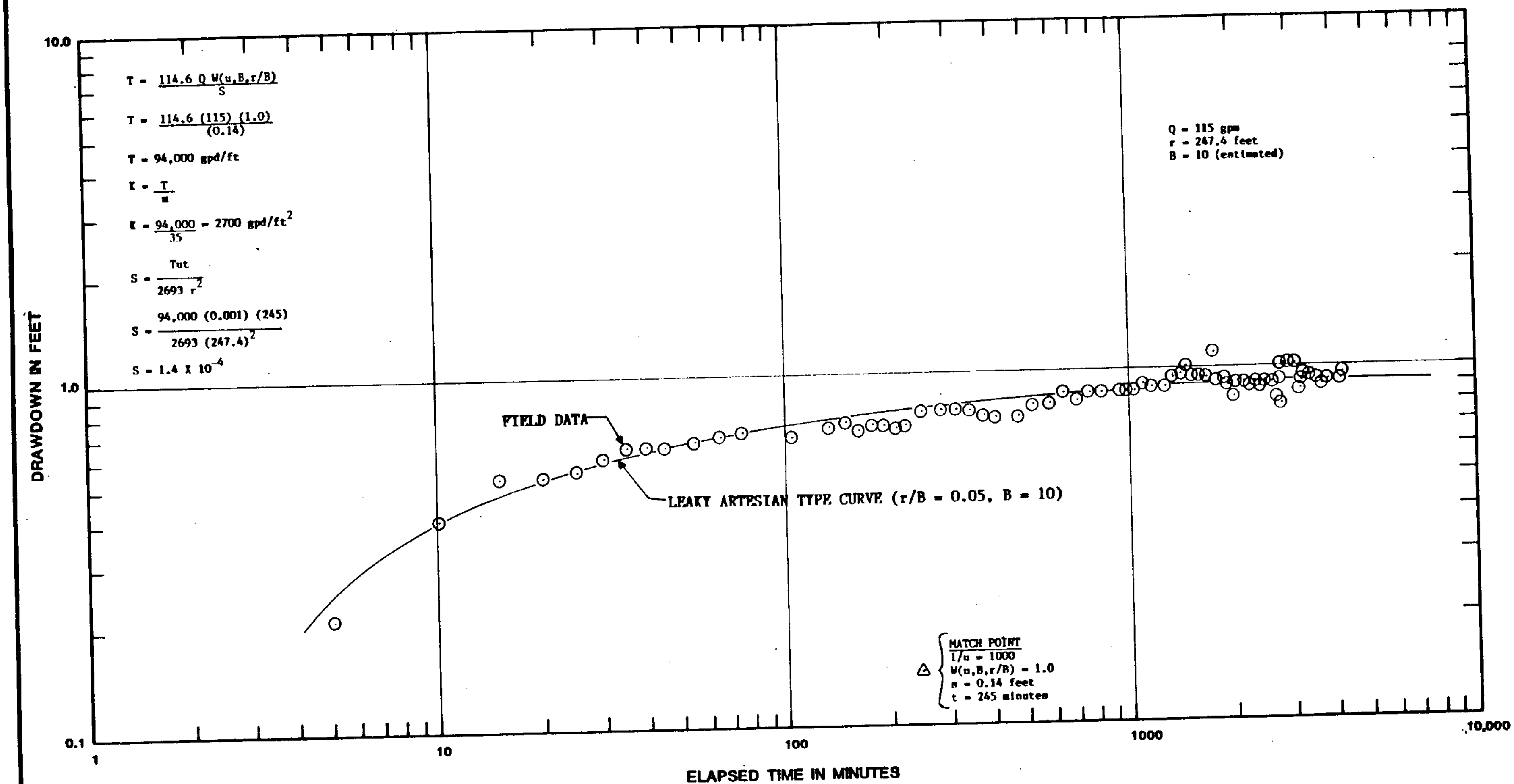

FIGURE 4 - 34
TIME - DRAWDOWN GRAPH
FOR WELL NO. 0161
AQUIFER TEST -
WELL NO. 747-1000
CIBA-GEIGY CORPORATION
TOMS RIVER PLANT

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aquitard at the Toms River plant. A number of hydraulic conductivity test methodologies were employed in order to improve the accuracy of the overall study. The methods used include the following:

Laboratory testing
In-situ slug testing
Long-term pump testing
Groundwater dating with naturally-occurring Tritium

<u>Test Location and Geologic Setting</u> - The site selected for the comprehensive aquitard tests lies immediately south of the existing wastewater treatment plant and west of the closed industrial landfill. The precise location can be identified by the location of well 193 on the topographic maps of the site. This site was selected for several reasons. First, the geology in this location is generally representative of the geology of the Toms River site. Second, groundwater in this location is uncontaminated. This latter fact simplifies the logistics of running a long-term pump test since the discharging groundwater need not be treated. Third, the test site is in close proximity to the main contaminant source areas at the Toms River plant.

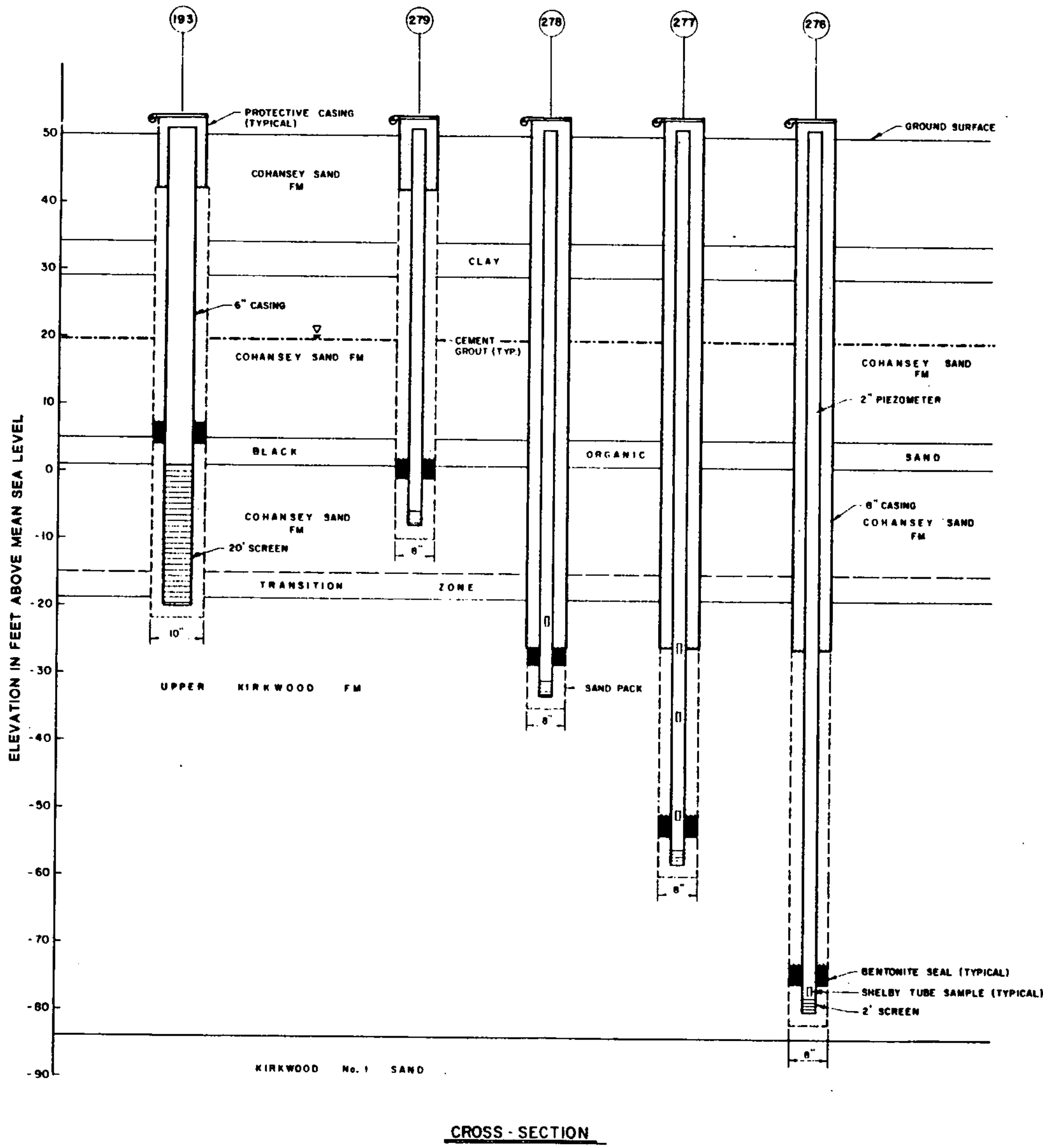
The geology of the test site is depicted in Figure 4-35. In this location, the Lower Cohansey Sand is absent, although a sandier zone in the Upper Kirkwood Aquitard is correlative with this unit. This sandier, more permeable zone in the Kirkwood lies approximately 20 feet below the top of the formation. The portion of the Kirkwood aquitard which was the focus of this study is that portion lying between the base of the primary Cohansey Sand and the No. 1 sand of the Kirkwood formation. In total, this zone has a thickness of approximately 65 feet. The hydraulic conductivity of the Lower Kirkwood aquitard, below the No. 1 sand, was not evaluated in this study.

<u>Laboratory Testing</u> - During the drilling of the piezometers and pumping well which form the basis of the Neuman and Witherspoon ratio method technique described subsequently, "undisturbed" Shelby tube samples were collected from the Kirkwood formation. These samples were subjected to a number of soil laboratory tests including:

Grain size distribution
Porosity and void ratio
Density
Atterberg Limits
Consolidation
Vertical hydraulic conductivity

The results of the general laboratory testing are presented in Table 4-14. The laboratory testing was subcontracted to Woodward-Clyde Consultants in Clifton, New Jersey.

The vertical hydraulic conductivity tests were performed employing a triaxial cell-based, constant volume, variable head permeameter. In a triaxial cell the soil specimen is enclosed in a flexible membrane and is under a confining pressure. The combination of the flexible membrane and the confining pressure minimizes the opportunity for leakage along the sides of the soil specimen. The confining pressure can also be varied to simulate in-situ conditions. The results of the laboratory hydraulic conductivity testing are given in Table



VERTICAL SCALE: I"=20'
HORIZONTAL SCALE: N.T.S.

FIGURE 4-35
GEOLOGIC CROSS - SECTION OF AQUITARD TEST SITE ILLUSTRATING WELL AND PIEZOMETER CONSTRUCTION
CIBA-GEIGY CORPORATION
TOMS RIVER PLANT

AWARE INCORPORATED

WEST MILFORD, NEW JERSEY
NASHVILLE, TENNESSEE

TABLE 4-14

SUMMARY OF LABORATORY TESTING OF
KIRKWOOD AQUITARD SAMPLES

Boring/Well Number	Sample Number	Depth (feet)	Atterburg Limits LL (%)	PL (%)	PI (%)	-200 Sieve (%)	($lb/ft.^3$)	Void Ratio (e)	Porosity (n)
P-3 (744-0278)	S-5	72.6	Non-plastic			21	121.1	0.891	.471
P-3 (744-0278)	S-4	76.5	Non-plastic			23.2	121.8	0.730	.422
P-2 (744-0277)	S-3	86.3	Non-plastic			29.0	120.3	0.595	.373
P-2 (744-0277)	S-2	100.2	- - -			86.5	111.7	-	-
P-1 (744-0276)	S-1	127.4	32	22	10	35.4	117.2	0.811	.448

4-15. With the exception of the test of the sample collected from 100.2 feet, the results of the laboratory hydraulic conductivity tests are quite consistent, ranging between 1.2×10^{-5} and 3.7×10^{-5} cm/sec. The single test result of 4.8×10^{-8} cm/sec reflects a particular soil specimen which was comprised of an unusually high clay content and is thus considered unrepresentative of the aquitard. Moreover, it is not believed that the clay zone encountered in this particular sample is continuous to a degree which would materially affect the overall effective hydraulic conductivity of the aquitard. Consequently, this test has been eliminated from further consideration of the test data.

In-Situ Slug (Recovery) Testing - As described subsequently, a pumping well and a series of piezometers were constructed in the Kirkwood formation and the overlying Cohansey Sand for the purposes of the aquifer/aquitard tests. These piezometers also provided an opportunity to perform in situ slug testing as a measure of formation hydraulic conductivity. The method utilized was that described by Horslev, 1951, where a volume of water is rapidly removed from the well or piezometer and the rate of water level recovery in the well is measured. The rapidity of the water level recovery in combination with considerations of the well's geometry permit a measurement of formation hydraulic conductivity in the vicinity of the well screen. It should be noted, however, that this method provides an hydraulic conductivity value which is generally representative of horizontal rather than vertical hydraulic conductivity.

Slug tests were performed on Piezometers 744-0276, 744-0277, and 744-0278 within the Kirkwood formation aquitard and Well 744-0193 within the Primary Cohansey Sand. The results of the recovery tests are also summarized in Table 4-16. The slug testing of Well 744-0193, screened in the Cohansey Sand, revealed an hydraulic conductivity of 1.2×10^{-2} cm/sec. This value is consistent with the results of recovery tests performed at numerous locations within the Cohansey Sand throughout the Toms River plant site. The hydraulic conductivity tests of the Kirkwood formation exhibit a variability in conformance with the observed variability in texture of the Kirkwood formation aquitard. The tests performed in the piezometers screened in the upper and lower portions of the Upper Kirkwood aquitard exhibited an hydraulic conductivity of 4.1×10^{-5} and 2.2×10^{-5} cm/sec, respectively. The test performed on Piezometer 744-0277 screened within the sandier, intermediate zone of the Upper Kirkwood aquitard exhibited a considerably higher hydraulic conductivity of 1.4×10^{-3} cm/sec. It is this zone which is correlative with the Lower Cohansey Sand found in other portions of the site.

Neuman and Witherspoon Ratio Method -The Neuman and Witherspoon Ratio Method (Neuman and Witherspoon, 1972) is a field technique for measurement of the vertical hydraulic conductivity of an aquitard over a relatively large area. It is an extension of the method developed by Hantush for analysis of leaky artesian aquifers (Hantush 1956). This technique permits estimation of vertical hydraulic conductivity of an aquitard. However, the Hantush technique is unable to differentiate between leakage from overlying and underlying aquitards. In the Neuman and Witherspoon Ratio Method, piezometers are constructed not only within the aquifer being pumped, but also within the aquitard being investigated. Specifically, the test requires a pumping well within the aquifer, at least one piezometer to measure drawdown within the aquifer, and at least two piezometers in the aquitard. The piezometers must be constructed at approximately the same radial distance from the pumping well. The test is conducted by pumping the well at a constant rate and observing

Table 4-15

RESULTS OF LABORATORY HYDRAULIC CONDUCTIVITY TESTING IN AQUITARD TEST AREA

Boring/Well Number	Sample No.	Depth (feet)	Hydraulic Conductivity (cm/sec)
P-3 (744-0278)	S-5	72.6	1.4×10^{-5}
P-2 (744-0277)	S-4	76.5	3.7×10^{-5}
P-2 (744-0277)	S-3	86.3	2.8×10^{-5}
P-2 (744-0277)	S-2	100.2	4.8×10^{-8}
P-1 (744-0276)	S-1	127.4	1.2×10^{-5}

TABLE 4-16

RESULTS OF SLUG TEST IN AQUITARD TEST AREA

Well Piezometer	Formation	Hydraulic Conductivity (in sm/sec)
Well 193	Cohansey Sand Aquifer	1.2×10^{-2}
P-3 (744-0278)	Upper Kirkwood Aquitard Upper Zone	4.1×10^{-5}
P-2 (744-0277)	Upper Kirkwood Aquitard Intermediate Zone	1.4×10^{-3}
P-1 (744-0276)	Upper Kirkwood Aquitard Lower Zone	2.2×10^{-5}

drawdown in the piezometers. The method permits calculation of the vertical hydraulic conductivity of various segments of the aquitard based upon the rate at which the drawdown observed in the aquifer is propagated vertically to the piezometers in the aquitard.

Test Methodology

Well and Piezometer Construction - Based on the properties of the Cohansey Sand aquifer observed in previous studies, a test array consisting of a pumping well screened within the Primary Cohansey Sand and four piezometers was developed. One piezometer was to be constructed within the primary Cohansey Sand. The remaining three piezometers were to be constructed at depths of 10, 45, and 60 feet below the top of the Kirkwood aquitard with their precise placement depending upon field conditions. Drilling and well construction was subcontracted to Engineering Drilling Company of Robbinsville, New Jersey. Work was performed during the period from January 6 to January 28, 1986 under the continuous supervision of a hydrogeologist from AWARE.

Drilling began with piezometer 744-0276 which also served as a pilot hole for detailed lithological characterization of the formations at the test site. The drilling advanced with continuous split-spoon sampling. Several "undisturbed" samples were also taken from deeper portions of the Kirkwood aquitard. The piezometers were constructed of 2-inch steel casing with two-foot lengths of wire-wound, stainless steel well screen. Of particular concern was the minimization of preferential groundwater flow through the annular space between the piezometer casing and the borehole. Any significant preferential migration of this type can severely jeopardize the validity of ratio method test results. Accordingly, the three piezometers screened within the Kirkwood aquitard were double-cased to all but eliminate preferential groundwater flow through the annular space. In each case, an 8-inch diameter steel casing was set and grouted into the top of the Kirkwood aquitard before the boreholes were advanced further. The piezometer well screens were sand packed to a height of several feet above the top of the well screen, and a bentonite pellet seal was then placed above the sand pack. The remaining annular space was tremie grouted with a bentonite/cement backfill mixture. The specific construction details of all of the piezometers and the pumping well are depicted on Figure 4-35.

Engineering Drilling Company initially experienced difficulty in constructing the pumping well. The principal reason for this difficulty appeared to be borehole plugging by drilling muds, which they were unable to overcome by conventional development techniques. The maximum yield of the well was approximately 40 gallons per minute--far below the typical capacity of wells founded in the primary Cohansey. Recognizing that the problem lay with faulty drilling procedures, Engineering Drilling Company agreed to redrill the well at no cost to Ciba-Geigy. In the event that similar difficulties were encountered in the drilling and construction of the replacement well, the original radial distance of 75 feet was shortened to 25 feet. Since the piezometers had already been constructed based upon a radial distance of 75 feet, the shortening of this distance resulted in some variability in the radial distances from the pumping well to each of the four piezometers. The differences however are slight and are not significant to the accuracy of the ratio method. The final alignment of the ratio method piezometer and well array is depicted in Figure 4-36.

Packer Assembly - It was anticipated that water level changes in the Cohansey Sand during the aquifer tests would occur very quickly. Consequently,

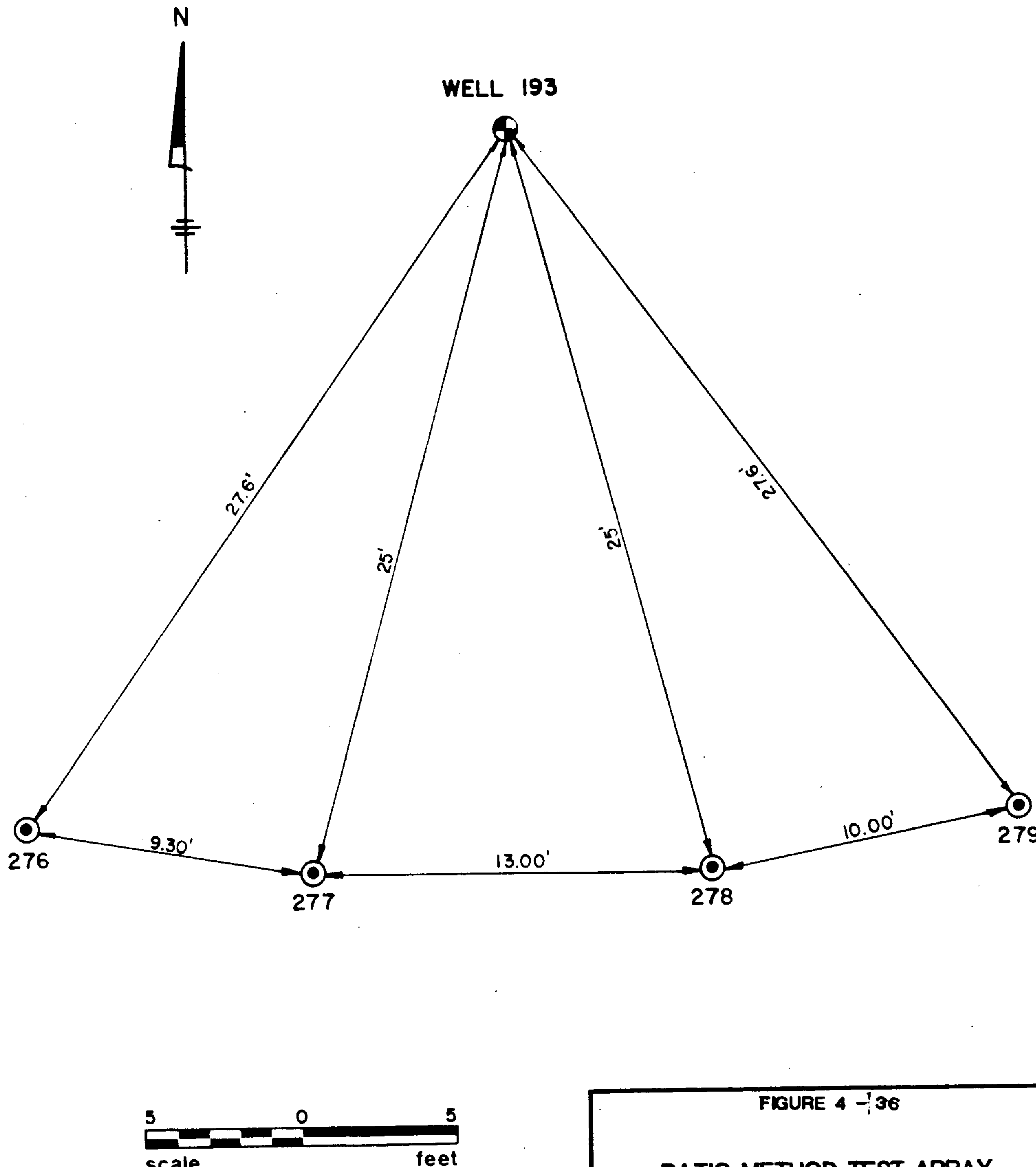


FIGURE 4 - 36

RATIO METHOD TEST ARRAY

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the sensitivity of the piezometer screened within the Cohansey Sand was enhanced by means of an inflatble packer assembly. This piezometer was fitted with a 2-inch diameter inflatable packer which was set just above the well screen. The pressure transducer was isolated below the inflatable packer to monitor water level changes in the aquifer. Packer assemblies were not used in the other piezometers because drawdowns occur more slowly within the aquitard and the well response factor for these piezometers was approximately 1.0 indicating no need for sensitivity enhancement (Black and Kipp, 1977).

<u>Water Level Trend Monitoring</u> - Water level trends in the piezometers were monitored during a 15-day period proceeding initiation of the pumping test. Water levels were monitored in each piezometer employing individual Hermit environmental data loggers and associated pressure transducers. The Hermit data logger was programmed to record water levels at 15-minute intervals throughout the monitoring period.

Barometric pressure was also recorded during this time period, employing a Cole-Parmer Model 8570 Barograph. The Cole-Parmer barometer was calibrated by comparison to values recorded at a local weather station. Results of the water level and barometric pressure monitoring are presented in Figure 4-37.

Several aspects of the water level trend monitoring results are noteworthy. First, there appears to be no correlation between barometric pressure fluctuations and water levels within the piezometers. It has therefore been concluded that barometric efficiency is not a significant consideration in evaluation of the aquifer test data. Barometric pressure was nonetheless recorded during the actual aquifer tests. Particularly noteworthy are the sudden and to date unexplainable water level fluctuations in Piezometers 744-0277 and 744-0278. Although, the reason is unknown, it is clear that the water level fluctuations did occur and are not erroneous data points. The primary and most compelling support for this contention is the fact that the totally independent measurements of water level fluctuation in Piezometers 744-0277 and 744-0278 coincide almost perfectly with one another during the first ten days of the test. Second, the water level fluctuations are recorded by a number of data points. There does not seem to be any conceivable way to attribute these fluctuations to equipment malfunction or measurement error. Nor can the fluctuations be correlated to barometric fluctuations. It seems most likely that these water level fluctuations are attributable to fluctuations in nearby pumping centers which are preferentially propagated through the intermediate higher hydraulic conductivity zone within the Kirkwood aquitard. Although this theory seems plausible, to date we have not been able to document any causitive pumping system fluctuations in either the Toms River Plant production wells or the existing purge well system. Research into this potential mechanism continues.

<u>Test Pumping Facilities</u> - The pumping well was equipped with a diesel engine-driven turbine pump. Pumping of the well as part of the aquifer test was subcontracted to W. C. Services of Woodbury, NJ. A digital flow meter was fitted to the discharge of the pump in order to monitor and record flow rate during the aquifer test. A gate valve was also placed on the discharge line to regulate flow rate. Flow rate during the aquifer test could therefore be adjusted by either adjusting the gate valve or by adjusting the operational rate of the diesel engine. The flow of the well was conducted by means of 4-inch diameter PVC pipe to the existing lined surface drainage channel surrounding the

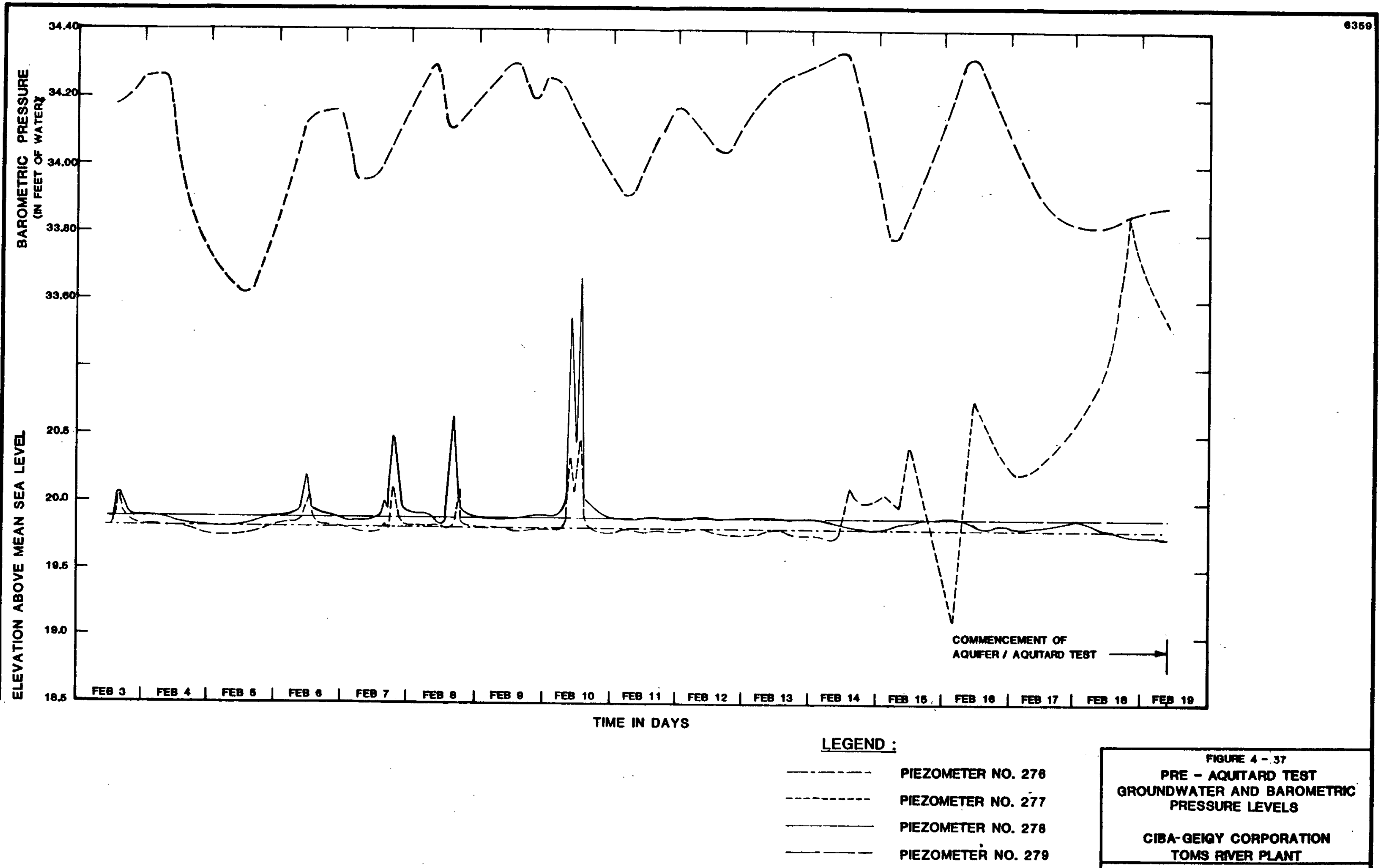

FIGURE 4 - 37

PRE - AQUITARD TEST
GROUNDWATER AND BAROMETRIC PRESSURE LEVELS

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AWARE INCORPORATED — WEST MILFORD, NEW JERSEY — NASHVILLE, TENNESSEE closed industrial landfill. The groundwater was discharged into the drainage system at a point approximately 650 feet from the pumping well. This was done to avoid any recharge of water back to the Cohansey Sand formation within the cone of influence of the aquifer test.

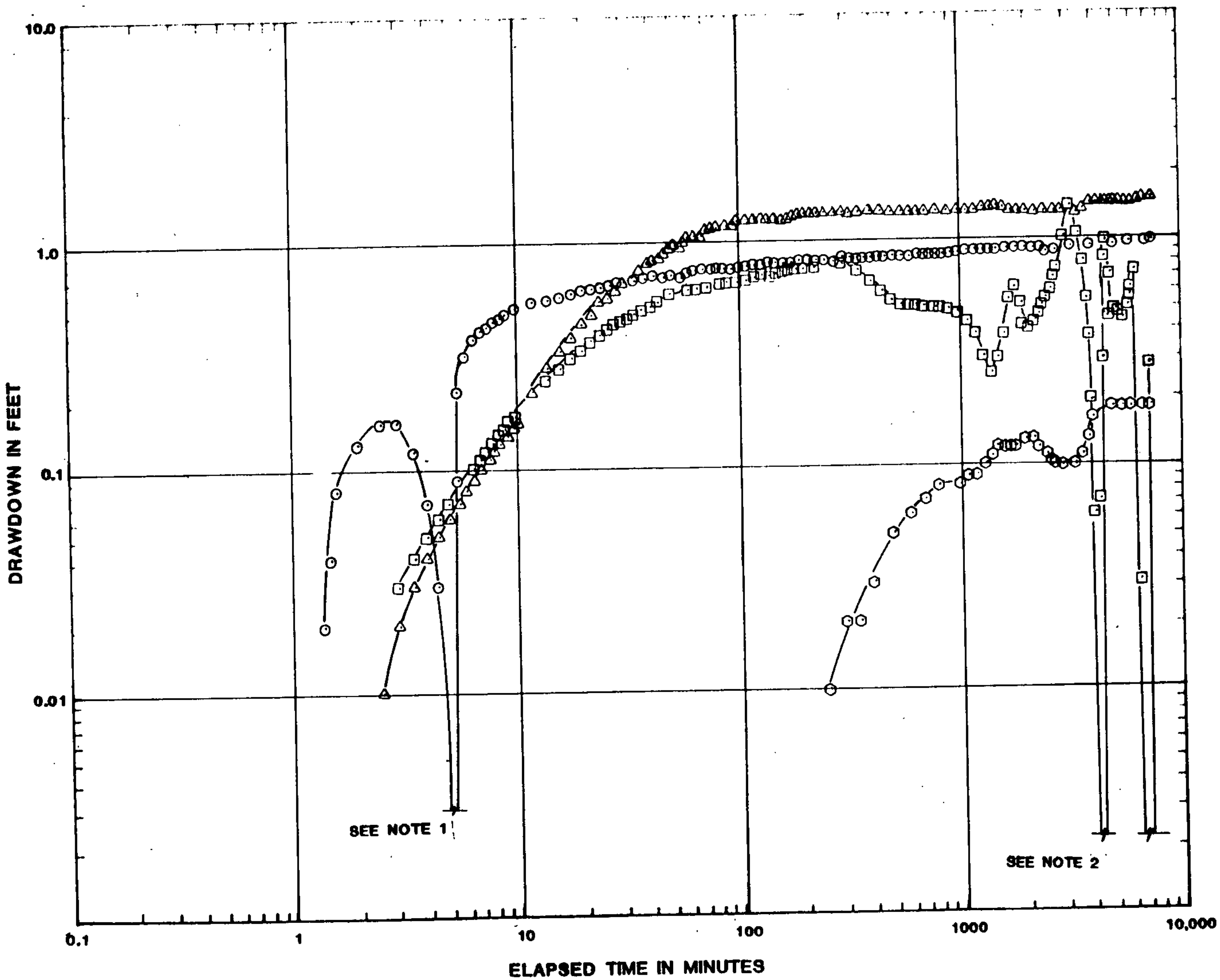
Test Start Up and Performance - Prior to start up of the test, the Hermit environmental data loggers were reprogrammed for collection of water level data on a logarithmic schedule. Programmed in this way, the Hermit environmental data loggers take water level readings at the following intervals:

Elapsed Time	Sample Interval
0-2 seconds	0.2 seconds
2-20 seconds	1 second
20-120 seconds	5 seconds
2-10 minutes	30 seconds
10-100 minutes	2 minutes
100-1000 minutes	10 minutes
1000-10,000 minutes	100 minutes

The test was begun by simultaneously starting the pump and the Hermit environmental data loggers. Based upon previous test pumping of the well, a target pumping rate of 75 gallons per minute was selected. Following start up, flow measurements were taken continuously, employing the digital water meter. The actual flow of the pumping well was determined to be 60 gallons per minute. This flow rate was to have been held constant throughout the remainder of the aquifer test. However, at a point about four minutes into the test the flow rate inexplicably declined. During the first three minutes of the test, a flow of 60 gallons per minute was observed. However, a flow measurement taken at approximately four minutes showed a rate of approximately 45 gallons per minute. No explanation for this decline in pumping rate could be found since no change in the RPMs of the diesel engine was observed. Nonetheless, a significant, albeit brief, decline in flow rate did occur approximately four minutes into the aquifer test. As will be noted subsequently, this momentary decline in the pumping rate was also manifested in the drawdown observed in the Cohansey Sand aquifer.

The test was run for a total period of 10,000 minutes although fluctuations in pumping rate and, consequently, in drawdown occurred after 7200 minutes due to diesel engine distress. Only data collected in the first 7200 minutes of the test is used in this analysis. Significant drawdown was observed in the deepest piezometer within the Kirkwood aquitard after 1000 minutes. The Neuman and Witherspoon ratio method is valid only for time periods prior to manifestation of drawdown at the base of the aquitard. After 10,000 minutes of operation, pumping was terminated. The recovery rates of the piezometers were then measured once again employing the logarithmic schedule of water level measurement. The recovery phase of the aquifer test was monitored for a period of another 2600 minutes after which the test was completed.

Data Analysis - Neuman and Witherspoon Ratio Methods - The drawdown data for the four piezometers observed during the first 7200 minutes of the aquifer/aquitard test are presented in Figure 4-38. Several features of the time drawdown graphs for the four piezometers are noteworthy. First, the observed reduction in discharge from the pumping well which occurred after four



LEGEND ;

- ⊙ PIEZOMETER NO. 276
- ⊡ PIEZOMETER NO. 277
- △ PIEZOMETER NO. 278
- ⊙ PIEZOMETER NO. 279

NOTES:
1. At t = 5 minutes, the water level in piezometer 279 was recorded at zero (0) drawdown.
2. At t = 4,200 minutes and at t = 6,600 through 7,100 minutes, the water levels in piezometer 277 indicated negative drawdown.

FIGURE 4 - 38

TIME - DRAWDOWN GRAPHS

COHANSEY - KIRKWOOD AQUIFER/ AQUITARD TESTS

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AWARE ENVIRONMENTAL — WEST MILFORD, NEW JERSEY — NASHVILLE, TENNESSEE minutes of pumping is clearly manifested in the time-drawdown graph for Piezometer 744-0279 which is screened in the Cohansey Sand. The decline in the rate of drawdown is not discernable in the time-drawdown graphs of the three piezometers screened within the Kirkwood aquitard.

Of particular note is the fact that drawdown was observed in Piezometers 744-0277 and 744-0278 quite soon after drawdown was realized in the Cohansey Sand aquifer. Moreover, the drawdown in Piezometer 744-0278 overtakes the drawdown in the Cohansey Sand aquifer (Piezometer 744-0279), after 30 minutes of pumping. Even the drawdown in the deeper Kirkwood aquitard piezometer, 744-0277, attains a drawdown equivalent to that observed in the Cohansey Sand aquifer after an elapsed time of 200 minutes.

The most likely reason for this atypical behavior is the significant difference in storativity that exists between the unconfined Cohansey Sand aquifer and the semi-confined interbedded sands within the Kirkwood aquitard. In the unconfined Cohansey Sand aquifer, drawdown induced by the pumping well is propagated radially outward from the pumping well relatively slowly due to the higher storativity of the aquifer. The storativity of the Cohansey Sand aquifer during early artesian time is 0.008. The storativity of the interbedded sands within the Kirkwood formation aquitard, on the other hand, is estimated to be 1×10^{-4}. Drawdown is therefore propagated more quickly in the interbedded sands due to the significantly lower storativity. It is believed that during the first few minutes of the aquifer test the extensive drawdown in the Cohansey Sand in the immediate vicinity of the pumping well was propagated vertically downward through the upper region of the Kirkwood aquitard. This drawdown was then propagated laterally through the intermediate higher hydraulic conductivity zone of the aquitard. The fact that this intermediate zone has a significantly lower storativity than the Cohansey Sand aquifer leads to the realization of greater drawdown in the intermediate zone of the Kirkwood aquitard than in the overlying pumped Cohansey Sand aquifer.

It is also noteworthy that Piezometer 744-0277 again exhibited the extreme water level fluctuations observed during the preaquifer test water level trend monitoring. Piezometer 744-0278, however, did not experience comparable water level fluctuations as was noted during the preaquifer test period. As before, these water level fluctuations cannot be correlated with barometric pressure fluctuations. A close examination of the water level fluctuations in Piezometer 744-0277 reveals that the peak drawdowns in this piezometer occur during midafternoon for each day of the five-day aquifer test. As yet, no explanation can be found for this phenomenon. However, unusual water level fluctuations during this type of analysis are not unprecedented. Wolf (1970) reports water level increases during application of the ratio method which were attributed to aquitard deformation. However, deformation is not believed to be the cause of the water level fluctuations observed in this test.

The graphs of the water level recovery in each piezometer following cessation of the aquifer test pumping are presented in Figure 4-39. The time-recovery graphs do not exhibit the unusual water level phenomenon observed in the time-drawdown graphs. The drawdowns appear to quite closely resemble the type of curves predicted by the Neuman and Witherspoon Ratio Method. Since the ratio method can be utilized with either time drawdown or time recovery data, the time recovery data were selected in this case.

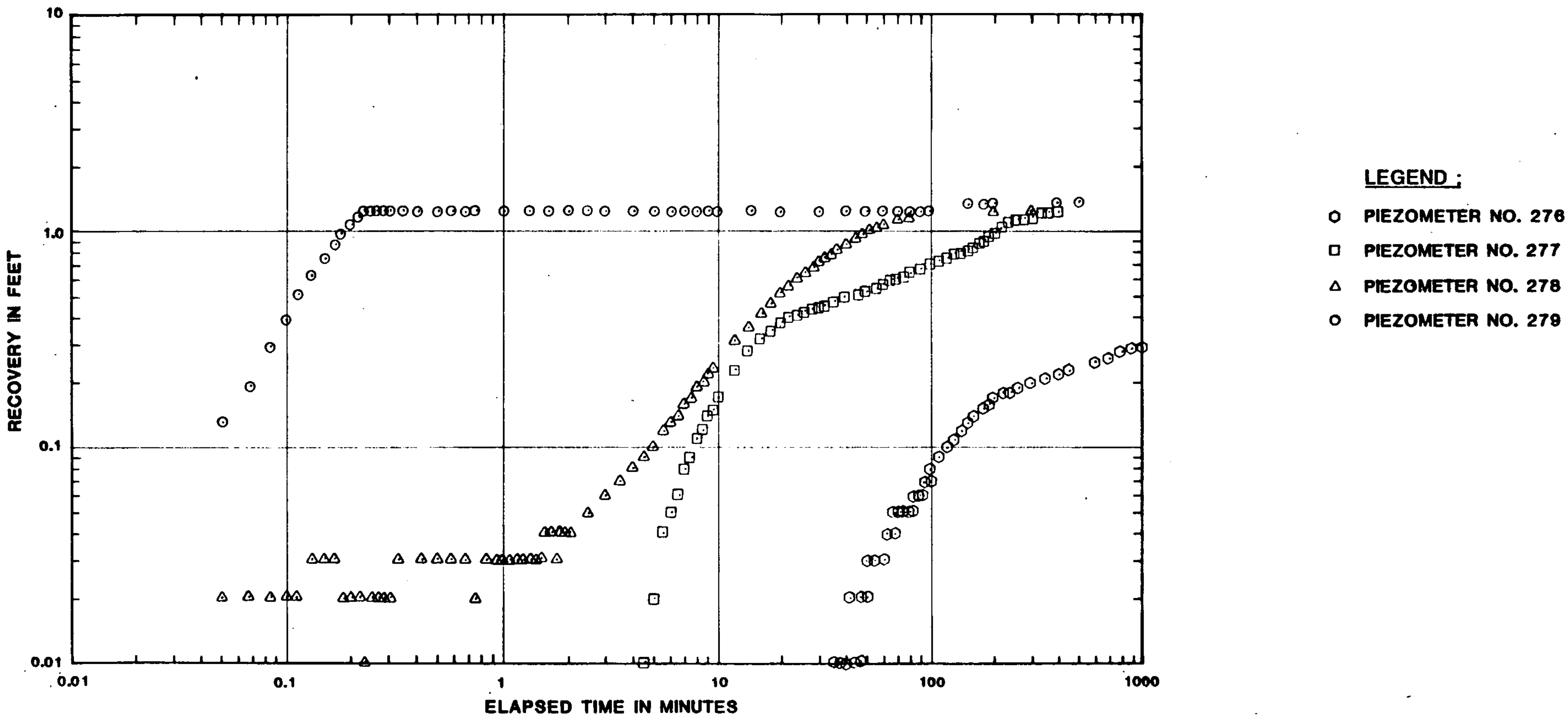

FIGURE 4-39

TIME – RECOVERY GRAPHS

COHANSEY – KIRKWOOD AQUIFER/ AQUITARD TEST

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In order to estimate the transmissivity of the Cohansey Sand aquifer at this location, the Jacob semilogarithmic method was utilized. The Theis type curve matching method is complicated by the coincident influences of leakage from the underlying Kirkwood aquitard and delayed gravity drainage in the Cohansey Sand. Figure 4-40 presents a semilogarithmic plot of the drawdown in Piezometer 744-0279 screened within the primary Cohansey Sand aquifer. The curvature of the field data caused by the combined effects of aquitard leakage and delayed gravity drainage is evident. Also evident is the drawdown lapse caused by the reduction of pumpage four minutes into the aquifer test. In order to avoid the effects of delayed gravity drainage and aquitard leakage, the Jacob method analysis was based on the drawdown observed in the first two minutes of the aquifer test when the impacts of these phenomena would be minimal. It should be noted, however, that at this time period u is considerably greater than 0.05 and therefore the Jacob method must also be considered as approximate. The transmissivity was determined to be 22,300 gallons per day per foot. The hydraulic conductivity of the Cohansey Sand is therefore 590 gallons per day per square foot or 2.8×10^{-2} cm/sec, based upon an aquifer thickness of 38 feet at this point. The storativity of the Cohansey Sand aquifer during its early semi-artesian behavior is 0.008.

Employing the Neuman and Witherspoon Ratio Method, the recovery in Piezometer 744-0279(s) 10 minutes after the cessation of pumping was 1.23 feet while the recovery in the aquitard piezometer, 744-0278 (s') was 0.25 feet. The ratio of s'/s therefore equals 0.20. Based upon the observed transmissivity and storativity of the aquifer, t_D can be calculated as follows:

$$t_D = \frac{9.28 \times 10^{-5}\ Tt}{Sr^2}$$

Where:
- t_D = Dimensionless time for pumped aquifer
- T = Transmissivity, gpd/ft
- t = Time, minutes
- S = Storativity, fraction
- r = Distance from pumping well to piezometers, feet

$$t_D = 3.42$$

From a graph of s'/s versus t_D developed by Neuman and Weatherspoon, it is possible to calculate t'_D. A value of 0.43 is obtained for the above values. The hydraulic diffusivity (') of the upper 9.5 feet of the aquitard can then be calculated from the following formula:

$$' = \frac{1.077 \times 10^4 t^1{}_D z^2}{T}$$

Where:
- ' = Hydraulic diffusivity, gpd/ft
- $t'_D{}^2$ = Dimensionless time for aquitard

$$' = 4.18 \times 10^4 \text{ gpd/ft}$$

Employing this same procedure for the data observed in piezometer 744-0277 it is possible to calculate the hydraulic diffusivity of the upper 35 feet of the aquitard. A hydraulic diffusivity of 2.63×10^5 gpd/ft is obtained.

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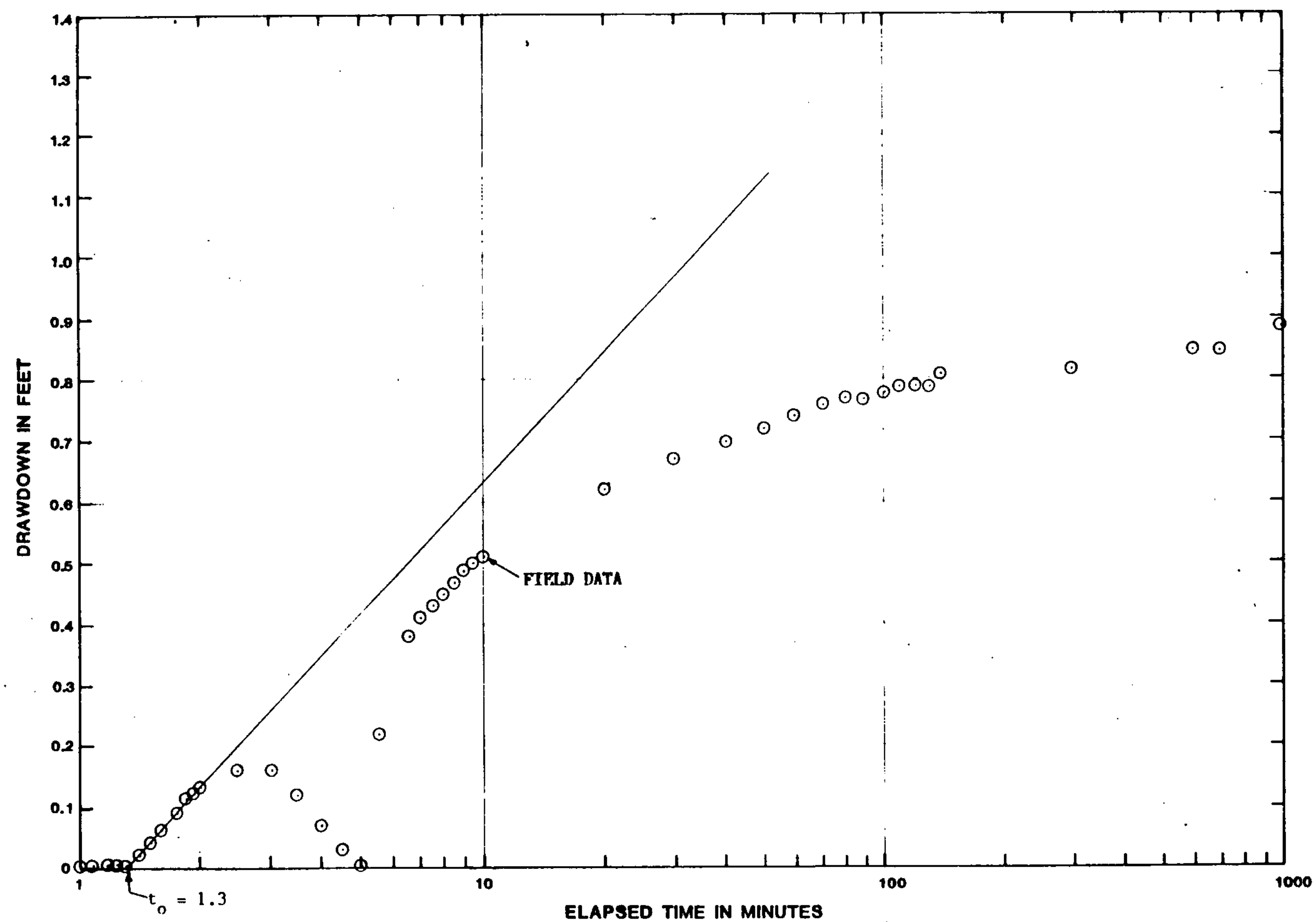

$$T = \frac{264\ Q}{S}$$

$$T = \frac{264\ (60)}{(0.71)}$$

T = 22,300 gpd/ft

$$K = \frac{T}{m}$$

$$K = \frac{22,300}{38} = 590\ \text{gpd/ft}^2$$

$K = 2.8 \times 10^{-2}$ cm/sec

$$S = \frac{Tt_o}{4800\ r^2}$$

$$S = \frac{22,300\ (1.3)}{4800\ (27.5)^2}$$

S = 0.008

FIGURE 4 - 40
TIME - DRAWDOWN GRAPH FOR PIEZOMETER NO. 279
COHANSEY - KIRKWOOD AQUIFER / AQUITARD TEST - JACOB METHOD

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Hydraulic diffusivity is the ratio of aquitard hydraulic conductivity to aquitard specific storage. In order to determine the hydraulic conductivity of the aquitard, then, aquitard specific storage must be determined. It was for this reason that "undisturbed" samples of the aquitard were subjected to consolidation tests. It is possible to calculate specific storage from the results of standard consolidation tests. Consolidation tests were run on five samples from the upper Kirkwood aquitard. The results are included in Volume IV. The compressibility of the aquitard can be derived from the slope of the stress/strain curve at the point where confining stress equals the ambient stress at the depth within the aquitard from which the sample was collected. The resultant aquifer compressibilities (a') were quite similar, ranging from 1.0×10^{-6} to 2.0×10^{-6} square feet per pound. The average compressibility of the aquifer is approximately 1.5×10^{-6} square feet per pound. The coefficient of compressibility can be calculated from the following relationship:

$$C_c = (1 + e_0)\, a'$$

Where: C_c = Coefficient of compressibility, ft^2/lb
e_0 = Initial void ratio, fraction
a' = Aquifer compressibility, ft^2/lb

Employing this relationship, the coefficient of compressibility of the aquitard was determined to be 2.75×10^{-6} ft^2/lb. The specific storage of the aquitard can then be calculated employing the following relationship:

$$S'_s = \frac{C_c\, w}{1+e_0}$$

Where: S'_s = Aquitard specific storage, ft^{-1}
w = Unit weight of water, lb/ft^3

Utilizing this relationship, the specific storage of the aquitard is found to be approximately 9.5×10^{-5} ft^{-1}. The hydraulic conductivity of both vertical sections of the aquitard can then be calculated by multiplying hydraulic diffusivity by specific storage as shown in Table 4-17.

Tritium Testing

The levels of tritium observed in Piezometers 744-0276 (P1) through 744-0279 (P4) are presented in Table 4-18. The observed level in the Cohansey Sand Piezometer 744-0279 (P4), is consistent with the levels observed in the tritium analyses described previously in this report. It seems clear that the tritium level observed in Piezometer 744-0276 (P1) is representative of a groundwater which originally recharged in approximately 1950. Assuming that precipitation contained 10 tritium units in 1950, groundwater resulting from recharge of that precipitation would be expected to exhibit approximately 1.3 tritium units today. The levels observed in Piezometer 744-0277 (P2) also seem to be representative of groundwater which originated as precipitation in the early 1950s. The level observed in Piezometer 744-0277 could either have originated as precipitation falling in 1959 or 1977. Contemporary levels of tritium in precipitation from those years would be expected to be roughly equivalent. The 1977 date is considered more likely to be correct as it appears to be consistent with known hydrogeologic conditions within the Cohansey Sand.

TABLE 4-17

RESULTS OF KIRKWOOD AQUITARD
TEST USING RATIO METHOD

Section of Aquitard Tested	Hydraulic Diffusivity (gpd/ft)	Specific Storage (ft^{-1})	Aquitard Vertical Hydraulic Conductivity gpd/ft^2	cm/sec.
Upper 9.5 Feet	4.18×10^4	9.5×10^{-5}	4.0	1.9×10^{-4}
Upper 35 Feet	2.63×10^5	9.5×10^{-5}	25	1.2×10^{-3}

Table 4-18

TRITIUM CONCENTRATIONS IN GROUNDWATER
AT AQUITARD TEST AREA

Boring/Well Number	Sample Number	Tritum Units
P-4 (744-0279)	S-4	19.10 ± 0.59
P-3 (744-0278)	S-3	28.75 ± 0.84
P-2 (744-0277)	S-2	2.45 ± 0.10
P-1 (774-0276)	S-1	1.60 ± 0.10

The estimated ages of the groundwater at Piezometers 744-0278 and 744-0276, which have a vertical separation of 45 feet, correspond to a vertical seepage velocity of 1.67 feet per year. It was concluded that dispersivity would have the effect of smoothing out the observed seasonal fluctuations in rainfall tritium levels but would not significantly alter the rate of advance of the tritium vertically through the aquitard. The vertical hydraulic conductivity of the aquitard can be calculated from the following equation:

$$k = \frac{V_s n_e}{i}$$

Where: V_s = seepage velocity, ft/day
n_e = effective porosity, fraction
i = hydraulic gradient, fraction
k = hydraulic conductivity, ft/day

The laboratory testing of the aquitard samples reveal that the average porosity is approximately 0.4. The vertical hydraulic gradient can be calculated from the water level monitoring conducted in the pretest trend monitoring period. It should be noted however, that the observed seepage velocity is based upon a time period of 27 years while the hydraulic gradient was measured over only a two-week period. The net seepage velocity, however, would be based upon the average hydraulic gradient existing over that 27 year period. It is likely that the vertical hydraulic gradient varies to some degree seasonally. Therefore, a limitation of this method of analysis is the fact that the hydraulic gradient used in the analysis is based upon a period of observation of only two weeks. Nonetheless, the variations in hydraulic gradient are likely to be small compared to the precision of other factors of the hydraulic conductivity testing. The differential water level between Piezometers 744-0276 and 744-0278 during the two week period of measurement was approximately 0.1 feet. The vertical separation of these two piezometers is 45 feet. Therefore, the vertical hydraulic gradient during the period of observation was approximately 0.002. Employing the above equation, the average hydraulic conductivity of the aquitard over this 45-foot distance is found to be 6.8 gallons per day per square foot or 3.2×10^{-4} cm/sec.

Aquitard Testing Conclusions - The results of the aquitard hydraulic conductivity testing employing all the test methods are presented in Table 4-19. A review of the data reveals significant variability in the results of the test methodologies. In evaluating the data, however, more credence must be given to the latter two methods, namely the Neuman and Witherspoon Ratio Method and the tritium analyses. The ratio method evaluates the effective vertical hydraulic conductivity of a large segment of the aquitard concident with the radius of influence of the aquifer cone of influence. It therefore can account for large scale lithologic variations and other macro-scale aquitard defects. Similarly, the tritium method is an observation of the actual rate of migration vertically through the aquitard and therefore also takes into account these factors.

Moreover, laboratory testing has often suggested lower hydraulic conductivities than actual (Olsen & Daniel, 1979). By virtue of the extremely small size of laboratory samples relative to the aquitard as a whole, laboratory samples often fail to predict the influence of macro-scale features on aquitard behavior. Recovery, or slug, tests also tend to underestimate actual hydraulic

TABLE 4-19
SUMMARY OF HYDRAULIC CONDUCTIVITY TESTING
UPPER KIRKWOOD AQUITARD

Subunit of Upper Kirkwood Formation	Lab Tests (Vertical k) (cm/sec)	Recovery Tests (Horizontal k) (cm/sec)	Ratio Method (cm/sec)	Tritium Analysis (cm/sec)
Upper Zone	2.6×10^{-5} [1]	4.1×10^{-5}	1.9×10^{-4}	
Intermediate Zone	-	1.4×10^{-3}	1×10^{-3}	3.2×10^{-4} [2]
Bottom Zone	1.2×10^{-5}	2.2×10^{-5}	-	

1 Average of three tests
2 Average hydraulic conductivity between piezometers 744-0278 and 744-0276

conductivity due to head losses in the gravel pack and well screen and formation scarring. Formation scarring appears to be particularly important in finer grained and interbedded deposits where smearing of finer grained deposits on the face of the borehole during drilling tends to diminish the hydraulic communication of the borehole with more permeable sandy lenses within the deposit. In such fine grained deposits, recovery tests can underestimate actual hydraulic conductivity by a factor of 10 or more. In more uniform and more permeable sediments, this factor tends to be lower but still present.

A number of conclusions can therefore be drawn from the results of this aquifer/aquitard test. These are as follows:

1. The Upper Kirkwood aquitard at the test site consists of three zones; an upper less permeable zone, an intermediate more permeable zone, and a deeper less permeable zone. The intermediate zone is apparently correlative with what has been termed the Lower Cohansey Sand on other parts of the site.

2. The vertical hydraulic conductivity of the upper and lower portions of the Upper Kirkwood aquitard appear to be approximately 1×10^{-4} cm/sec. The intermediate zone has an hydraulic conductivity of approximately 1×10^{-3} cm/sec.

3. The overall effective vertical hydraulic conductivity of the Upper Kirkwood aquitard at this site is approximately 1×10^{-4} cm/sec.

4. The hydraulic conductivity of the primary Cohansey Sand aquifer at the test site is 590 gallons per day per square foot or 2.8×10^{-2} cm/sec. The transmissivity of the primary Cohansey sand aquifer at this point is 22,300 gallons per day per foot, based on a saturated thickness of 38 feet.

5. The specific storage of the Upper Kirkwood aquitard is 1×10^{-4} ft^{-1}.

Summary of Hydraulic Conductivity Testing

As described above, hydraulic conductivity testing using both field and laboratory methods has been conducted at the Toms River Plant. In fact, the volume of reliable field data far exceeds that which is typically assembled during a remedial investigation. Because the aquifer/aquitard pump testing and isotope methods integrate the hydraulic conductivity over a proportionally much larger area, these methods should be accorded the greatest weight when selecting representative values for use in analytical or digital models. Laboratory tests, because of their very small sample size and the difficulty in collecting a representative, "undisturbed" sample, should be interpreted with caution.

The Horslev-method, variable head test methods typically underestimate the actual hydraulic conductivity by a factor ranging from two to greater than ten. Several factors contribute to the underestimation. Perhaps the most significant is that the in-situ tests sample a relatively small volume of the aquifer and are less likely to include the most permeable pathways that control the effective hydraulic conductivity of the system. In addition, the installation of a monitoring well inevitably disturbs the formation, resulting in smearing of finer-grained materials on the walls of the borehole. Finally, the in-situ methods do not account for frictional head losses as water passes through the well screen. On this project, comparison of slug test results at the Cohansey Sand at locations where aquifer tests have been conducted indicates that the slug test values are less then aquifer test values by a factor ranging from 2.3 to 3.6. A typical factor of 2.0 to 3.0 is probably, therefore, appropriate.

With these considerations in mind, the available hydraulic conductivity data are assessed and representative values are selected in the discussion that follows. The estimates are summarized on Table 4-20.

Kirkwood No. 2 Sand

In-situ hydraulic conductivity tests performed on monitoring wells installed in the Kirkwood No. 2 Sand indicate a hydraulic conductivity on the order of 7.0 x 10^{-3} cm/sec. Applying an adjustment factor of 3.0, we estimate the effective hydraulic conductivity to be on the order of 2.1 x 10^{-2} cm/sec. With a typical thickness on the order of ten feet, the estimated transmissivity of this unit would be on the order of 4,450 gpd/ft.

Primary Kirkwood

On the basis of laboratory testing, the estimated effective vertical hydraulic conductivity of the Primary Kirkwood is on the order of 1.0 x 10^{-5} cm/sec (0.21 gpd/ft^2).

Kirkwood No. 1 Sand

Available in-situ tests of the Kirkwood No. 1 Sand indicate an hydraulic conductivity on the order of 5.0 x 10^{-3} cm/sec. Applying an adjustment factor of 3.0, the estimated effective hydraulic conductivity is on the order of 1.5 x 10^{-2} cm/sec (320 gpd/ft^2). With a typical thickness on the order of 25 feet, the estimated transmissivity is 8,000 gpd/ft.

Upper Kirkwood

The Neuman-Witherspoon Ratio Method analysis and the tritium testing indicate that the effective vertical hydraulic conductivity of the Upper Kirkwood is on the order of 1.0 x 10^{-4} cm/sec (2.1 gpd/ft^2). The intermediate zone within the Upper Kirkwood that is stratigraphically equivalent to the Lower Cohansey, has an effective hydraulic conductivity on the order of 1.0 x 10^{-3} cm/sec (21.2 gpd/ft^2).

Lower Cohansey

Due to the nature of its depositional history, the hydraulic conductivity of the Lower Cohansey is quite variable. In the area of the contaminant plume, however, the Lower Cohansey is similar in character to the Primary Cohansey. An aquifer test performed near this area in 1956 indicated an hydraulic conductivity on the order of 3.9 x 10^{-2} cm/sec (830 gpd/ft^2). It is believed that this value is a reasonable estimate of the effective hydraulic conductivity of the Lower Cohansey. With a typical thickness of 20 to 30 feet, the estimated transmissivity is in the range of 17,000 to 25,000 gpd/ft.

TABLE 4-20

SUMMARY OF HYDRAULIC CONDUCTIVITY ESTIMATES

Primary Cohansey

4.5×10^{-2} cm/sec
(954 gpd/ft^2)

Cohansey/Kirkwood Transitional Unit

1.0×10^{-4} cm/sec
(2.1 gpd/ft^2)

Lower Cohansey

3.9×10^{-2} cm/sec
(830 gpd/ft^2)

Upper Kirkwood

1.0×10^{-4} cm/sec
(2.1 gpd/ft^2)

Kirkwood No. 1 Sand

1.5×10^{-2} cm/sec
(320 gpd/ft^2)

Primary Kirkwood

1.0×10^{-5} cm/sec
(0.21 gpd/ft^2)

Kirkwood No. 2 Sand

2.1×10^{-2} cm/sec
(445 gpd/ft^2)

Cohansey/Kirkwood Transitional Unit

Relatively little data regarding the hydraulic conductivity of this unit are available. Based on a single laboratory test and the lithology of this unit, it is estimated that the effective vertical hydraulic conductivity is approximately 1.0×10^{-4} cm/sec (2.1 gpd/ft^2).

Primary Cohansey

Aquifer tests of the Primary Cohansey provide transmissivity values ranging from 22,300 gpd/ft to 94,000 gpd/ft, with a corresponding hydraulic conductivity range of 590 gpd/ft^2 (2.8×10^{-2} cm/sec) to 2,700 gpd/ft^2 (1.3×10^{-1} cm/sec). In consideration of the strengths and weaknesses of all the data, it is thought that the hydraulic conductivity of the Primary Cohansey is in the range from 850 gpd/ft^2 (4.0×10^{-2} cm/sec) to 1,060 gpd/ft^2 (5.0×10^{-2} cm/sec). The transmissivity of the Primary Cohansey varies in accordance with the saturated thickness.

4.4 Groundwater Conditions

In the previous section, the relationships of the various stratigraphic units beneath the site were presented. In this section, the manner in which these stratigraphic units combine to form distinct hydro-stratigraphic units will be described. As will be seen, several stratigraphic units can often be assigned to a single "water-bearing unit" that (from a regional perspective) will behave largely as a single entity from the standpoint of groundwater flow. In addition, differences may occur between truly regional associations and local or quasi-regional definitions of hydro-stratigraphic units. From a regional standpoint, at least two major aquifer systems are present within the Toms River region: the Kirkwood aquifer system and the water-table aquifer system (Anderson and Appel, 1969).

The Kirkwood Aquifer System

The Kirkwood aquifer system typically consists of laterally persistent, water-bearing sands, interbedded with thin silts and clays, which are presumably equivalent to the "Atlantic City 800-foot sand", a major water-bearing zone within the Kirkwood in Atlantic County. On a regional basis the water-bearing zones within the Kirkwood receive the bulk of their recharge via vertical leakage from the overlying water table aquifer and typically behave as confined or semi-confined aquifers (Anderson and Appel, 1969).

The Kirkwood aquifer system is intensely developed for public water supplies along the coast and in the Toms River region. According to Anderson and Appel (1969), the yields of 44 public supply wells in the Kirkwood ranged from 38 gpm to 1,225 gpm with an average of 417 gpm. Specific capacities ranged from 1 to 30 gpm per foot, with an average of 11 gpm per foot.

The Water Table Aquifer System

The water-table aquifer system in the Toms River area consists of the combined thickness of the Cohansey, Pennsauken, and Cape May formations. The water-table aquifer generally behaves as an unconfined system although locally, confined or semi-confined conditions may exist (Anderson and Appel, 1969). Semi-confined conditions were observed during an aquifer test conducted for this investigation in the vicinity of recovery well 747-1000. The water-table aquifer receives the vast majority of its recharge through the direct infiltration of precipitation. Along the major drainageways such as the Toms River, recharge from the underlying Kirkwood system may contribute a significant quantity of water to the upper aquifer.

Pumpage from the water-table aquifer in the Toms River region is significant, with reported yields of 30 industrial and public supply wells ranging from 65 gallons per minute (gpm) to 665 gpm, with an average of 323 gpm. Specific capacities ranged from 2 to 39 gpm per foot with an average of 13 gpm per foot (Anderson and Appel, 1969).

Well fields operated by the Toms River Water Company include production wells screened in both the Kirkwood and water table aquifer systems, with a combined estimated pumpage on the order of seven million gallons per day (about 4,860 gpm). The two major well fields are the Parkway Station well field and the Holly Street well field (Figure 3-1).

On a more local basis each of the major aquifer systems can be recognized to consist of several distinct water-bearing zones separated by aquitards of variable efficiency. For example, within the area of this investigation we have identified two distinct water-bearing zones within the Kirkwood Formation which we have termed the Kirkwood #1 and #2 sands. Similarly, the Cohansey Formation can be shown to consist locally of at least two, if not three, water-bearing zones, namely, the Lower Cohansey, Primary Cohansey, and perhaps, the Upper Cohansey. For the latter case, in particular, it is not suggested that the water-bearing zones are hydraulically isolated, distinct aquifers. Instead, it is recognized that the stratigraphic sequence provides vertical hydraulic conductivity differentials which can be of significance to the directions of groundwater flow, and perhaps more importantly, to the migration of contaminants within the groundwater system.

4.4.1 Groundwater Flow

In this section the patterns of groundwater flow within and between the various water-bearing zones, as well as the physical characteristics of the major water-bearing units are described. The report then describes, in the following section, the occurrence of contamination or the likelihood of contamination within these water-bearing zones. The water-bearing zones will be described in stratigraphic sequence, i.e., from the deepest to the most shallow. Groundwater elevation data are presented in Table 4-21 and in Volume IV.

Kirkwood No. 2 Sand Water-Bearing Zone

The Kirkwood No. 2 Sand Water-Bearing Zone is contained within the lithostratigraphic unit of the same name. Nine monitoring wells were installed within this unit and have been used to develop piezometric surface contour maps for this zone. Figure 4-41 illustrates the configuration of hydraulic head within the Kirkwood No. 2 Sand on November 15, 1985. The contour map indicates a generally southeastward direction of groundwater flow with local components towards the Toms River valley from both sides of the Toms

TABLE 4-21

Selected Groundwater Elevation Data

Well Number	South Coordinate	East Coordinate	Top of Casing Elevation	Ground Surface Elevation	Depth to Groundwater (in feet) 19-Nov-85	Depth to Groundwater (in feet) 19-Feb-86	Groundwater Elevation (in feet) 19-Nov-85	Groundwater Elevation (in feet) 19-Feb-86
744-0071D	129.94	5134.91	17.79	17.79	4.88	4.11	12.91	13.68
744-0071S	93.00	5147.00	17.47	17.47	5.17	4.08	12.30	13.39
744-0073D	-651.00	4998.05	22.33	22.33	9.09	7.97	13.24	14.36
744-0073S	-652.00	4983.00	22.65	22.65	7.84	8.15	14.81	14.50
744-0074D	-952.64	4474.95	18.44	18.44	3.58	2.47	14.86	15.97
744-0074S	-949.00	4464.00	17.94	17.94	5.10	4.04	12.84	13.90
744-0075D	-854.42	4372.82	15.54	15.54	0.92	0.35	14.62	15.19
744-0075S	-852.00	4378.00	15.54	15.54	2.58	2.63	12.96	12.91
744-0101A	2400.00	2050.00	52.18	50.39	34.16	34.29	18.02	17.89
744-0102A	3025.00	2050.00	67.63	65.90	50.18	50.29	17.45	17.34
744-0103	2150.00	2780.00	52.48	51.64	28.25	26.79	24.43	25.69
744-0104A	2609.67	2753.73	53.24	49.45	26.54	25.71	26.70	27.53
744-0105A	3150.00	2780.00	51.43	49.27	35.55	35.56	15.88	15.87
744-0106A	1910.00	2415.00	43.33	41.96	26.27	25.94	17.06	17.39
744-0107	3420.00	2515.00	56.79	55.30	30.48	30.30	26.31	26.49
744-0108A	1617.00	2121.20	53.46	50.80	35.29	35.25	18.17	18.21
744-0109	1654.22	1551.83	51.47	50.21	32.04	32.09	19.43	19.38
744-0110A	1386.52	1815.27	49.25	47.91	30.06	30.10	19.19	19.15
744-0111	1877.13	1841.27	54.45	52.83	21.60	20.80	32.85	33.65
744-0112	4022.50	3868.40	53.38	51.93	36.67	39.70	16.71	13.68
744-0113	2103.38	4482.28	32.92	32.07	19.42	19.05	13.50	13.87
744-0114	826.59	3987.22	52.36	51.04	37.51	37.17	14.85	15.19
744-0115	-1488.24	2936.12	25.07	23.58	9.00	8.34	16.07	16.73
744-0117	1809.30	2483.59	42.09	40.39	25.03	24.98	17.06	17.11
744-0118	1777.23	2991.35	30.50	28.93	14.12	13.87	16.38	16.63
744-0119	2002.72	3656.74	28.28	26.50	13.64	13.36	14.64	14.92
744-0120	2014.03	3653.74	28.51	26.00	13.97	13.72	14.54	14.79
744-0121	2266.58	3337.79	37.04	36.00	22.23	22.06	14.81	14.98
744-0122	3166.09	2108.00	61.17	57.39	43.52	43.56	17.65	17.61

TABLE 4-21, continued

Selected Groundwater Elevation Data

Well Number	South Coordinate	East Coordinate	Top of Casing Elevation	Ground Surface Elevation	Depth to Groundwater (in feet)		Groundwater Elevation (in feet)	
					19-Nov-85	19-Feb-86	19-Nov-85	19-Feb-86
744-0123	3148.32	2760.51	52.57	50.15	25.88	25.25	26.69	27.32
744-0124	-1009.03	3509.76	28.84	26.84	NA	12.90	NA	15.94
744-0125	-1011.45	3512.43	28.38	26.84	13.47	12.76	14.91	15.62
744-0126	-822.50	4012.07	25.01	23.00	10.00	9.10	15.01	15.91
744-0127	-821.56	4015.08	25.22	23.00	10.22	9.41	15.00	15.81
744-0128	-758.10	4234.46	25.18	23.10	NA	10.87	NA	14.31
744-0129	-755.99	4236.54	25.39	23.10	10.60	9.77	14.79	15.62
744-0131	-97.45	2683.46	63.82	61.65	NA	44.91	NA	18.91
744-0132	142.00	1275.84	57.73	54.77	36.66	36.44	21.07	21.29
744-0133	357.43	1800.70	55.18	53.04	35.05	34.86	20.13	20.32
744-0134	561.08	1810.57	53.48	51.15	33.43	33.23	20.05	20.25
744-0135	685.38	1364.56	51.89	49.29	31.17	31.07	20.72	20.82
744-0136	-441.07	4558.89	26.16	23.28	12.95	13.34	13.21	12.82
744-0137	1397.08	2549.96	41.08	39.23	22.97	23.06	18.11	18.02
744-0138	1790.00	2721.68	42.52	42.77	25.54	25.26	16.98	17.26
744-0139	2316.29	3568.76	48.56	46.31	34.17	34.40	13.39	14.16
744-0140	2492.16	3819.00	53.43	51.55	39.81	39.64	13.62	13.79
744-0141	2493.00	3814.20	53.91	51.55	40.22	40.08	13.69	13.83
744-0142	2910.73	3309.41	52.98	49.84	38.01	37.95	14.97	15.03
744-0143	2424.87	4391.99	44.35	43.40	31.03	30.83	13.32	13.52
744-0144	2428.13	4393.75	44.94	43.40	31.73	31.45	13.21	13.49
744-0146	-2712.23	1135.50	40.18	37.47	20.91	19.77	19.27	20.41
744-0150	2705.38	4315.75	50.15	48.77	37.58	36.78	12.57	13.37
744-0151	-1744.51	-3740.02	73.27	71.31	42.85	43.68	30.42	29.59
744-0152	3969.29	1233.40	68.67	67.06	50.38	50.38	18.29	18.29
744-0153	2103.20	4487.87	33.65	31.56	20.21	19.85	13.44	13.80
744-0154	2240.73	3741.09	44.26	41.87	30.18	29.96	14.08	14.30
744-0155	2492.16	3819.00	53.89	51.55	40.27	40.12	13.62	13.77
744-0156	2742.16	3819.00	58.70	54.16	45.32	45.22	13.38	13.48

TABLE 4-21, continued

Selected Groundwater Elevation Data

Well Number	South Coordinate	East Coordinate	Top of Casing Elevation	Ground Surface Elevation	Depth to Groundwater (in feet)		Groundwater Elevation (in feet)	
					19-Nov-85	19-Feb-86	19-Nov-85	19-Feb-86
744-0157	2991.86	3813.30	60.80	57.68	47.34	47.28	13.46	13.52
744-0158	2987.37	4232.50	53.66	51.37	40.40	40.31	13.26	13.35
744-0159	3271.15	4156.79	59.52	57.68	46.12	46.09	13.40	13.43
744-0160	1021.08	3532.00	56.19	53.29	40.03	39.70	16.16	16.49
744-0161	2117.86	2987.67	43.65	43.54	27.75	27.57	15.90	16.08
744-0162	3547.60	4079.70	57.78	55.29	44.19	44.21	13.55	13.53
744-0163	483.17	814.29	63.28	61.26	40.40	39.55	22.88	23.73
744-0164	246.55	1797.17	57.38	54.29	37.37	37.22	20.01	20.16
744-0165	2687.12	4322.30	49.59	48.33	36.24	36.08	13.35	13.51
744-0166	2404.30	4398.53	45.32	42.19	32.00	31.77	13.32	13.55
744-0167	2479.74	3813.20	53.28	51.17	39.46	39.31	13.82	13.97
744-0168	2100.00	2994.89	42.84	42.89	26.89	26.68	15.95	16.16
744-0169	3543.07	6457.08	13.84	13.84	5.54	4.88	8.30	8.96
744-0170	4063.90	6506.52	15.44	15.44	5.08	4.40	10.36	11.04
744-0171	4217.62	6858.33	17.76	17.76	10.09	9.46	7.67	8.30
744-0172	5296.62	7282.02	12.64	12.64	5.20	4.37	7.44	8.27
744-0173	6293.07	7622.17	12.14	12.14	6.22	5.75	5.92	6.39
744-0174	1935.35	4130.00	28.01	25.14	13.97	13.64	14.04	14.37
744-0175	1641.22	3127.75	42.04	39.80	25.44	25.12	16.60	16.92
744-0176	-609.54	3102.22	30.79	29.20	13.78	13.15	17.01	17.64
744-0177	-592.13	3600.88	29.46	27.70	13.74	13.22	15.72	16.24
744-0178	-736.15	3604.65	26.96	25.30	11.67	11.38	15.29	15.58
744-0179	-84.63	2668.56	63.61	61.90	45.08	45.50	18.53	18.11
744-0180	122.13	5130.35	18.13	18.13	0.59	2.22	17.54	15.91
744-0181	2674.86	4313.58	50.10	48.50	33.17	33.88	16.93	16.22
744-0182	928.18	349.62	62.16	59.90	40.68	40.43	21.48	21.73
744-0183	933.03	342.93	61.80	60.00	40.68	39.22	21.12	22.58
744-0184	935.95	341.49	61.53	59.70	38.71	38.24	22.82	23.29
744-0185	-710	5375	23.57	NA	NA	6.72	NA	16.85

TABLE 4-21, continued

Selected Groundwater Elevation Data

Well Number	South Coordinate	East Coordinate	Top of Casing Elevation	Ground Surface Elevation	Depth to Groundwater (in feet)		Groundwater Elevation (in feet)	
					19-Nov-85	19-Feb-86	19-Nov-85	19-Feb-86
744-0186	-710	5375	23.33	NA	NA	6.58	NA	16.75
744-0187	-1430	5380	31.15	NA	NA	13.10	NA	18.05
744-0188	-1430	5380	31.13	NA	NA	12.76	NA	18.37
744-0189	-1890	3720	23.57	NA	NA	8.98	NA	14.59
744-0190	-1890	3720	23.31	NA	NA	7.97	NA	15.34
744-0191	-2105	4440	25.75	NA	NA	6.35	NA	19.40
744-0192	-2105	4440	25.57	NA	NA	6.54	NA	19.03
744-0193	1570	1210	54.24	NA	NA	NA	NA	NA
744-0194	-130	3360	50.52	48.40	NA	34.13	NA	16.39
744-0195	-130	3360	50.67	48.38	NA	33.87	NA	16.80
744-0196	-620	2610	55.97	53.63	NA	38.10	NA	17.87
744-0197	-620	2610	55.81	53.60	NA	37.69	NA	18.12
744-0198	-1300	2940	46.43	44.56	NA	29.54	NA	16.89
744-0199	-1300	2940	46.46	44.30	NA	30.54	NA	15.92
744-1100	-1735	35	66.38	64.19	NA	NA	NA	NA
744-1101	-1735	35	66.04	64.18	NA	NA	NA	NA
744-1102	435	150	61.15	58.93	NA	NA	NA	NA
744-1103	435	150	61.20	59.49	NA	NA	NA	NA
744-1104	-415	1845	68.18	66.13	NA	NA	NA	NA
744-1105	-415	1845	68.00	65.96	NA	NA	NA	NA
744-1106	-1735	1000	65.41	63.38	NA	NA	NA	NA
744-1107	-1735	1000	65.19	63.32	NA	NA	NA	NA
744-1108	490	305	54.23	52.14	NA	NA	NA	NA
744-1109	320	297	56.26	54.04	NA	NA	NA	NA
744-1110	480	815	63.84	62.17	NA	NA	NA	NA
744-0203	3957.65	2135.73	61.46	NA	dry	NA	DRY	DRY
744-0206	1906.56	2406.52	43.56	NA	dry	NA	DRY	DRY
744-0207	200	3672	28.55	25.65	12.64	13.13	15.91	15.42

TABLE 4-21, continued

Selected Groundwater Elevation Data

Well Number	South Coordinate	East Coordinate	Top of Casing Elevation	Ground Surface Elevation	Depth to Groundwater (in feet)		Groundwater Elevation (in feet)	
					19-Nov-85	19-Feb-86	19-Nov-85	19-Feb-86
744-0208	200.39	3672.21	28.12	25.58	13.17	13.25	14.95	14.87
744-0222	1776.67	2721.42	41.11	40.78	24.16	23.91	16.95	17.20
744-0232	3042.00	2772.55	49.17	48.53	22.33	21.69	26.84	27.48
744-0233	2996.40	2802.90	51.77	48.42	33.05	33.14	18.72	18.63
744-0235	421.15	1856.95	53.85	52.50	34.02	33.87	19.83	19.98
744-0236	201.25	1772.85	53.88	53.45	33.69	33.53	20.19	20.35
744-0237	173.97	1503.85	54.39	53.89	33.68	33.48	20.71	20.91
744-0239	2119.00	3734.71	40.69	38.05	26.37	26.13	14.32	14.56
744-0240	2113.00	3734.17	39.47	38.05	25.20	24.93	14.27	14.54
744-0241	2476.63	4101.3	37.20	33.78	23.68	23.42	13.52	13.78
744-0242	2470.63	4101.30	36.84	33.78	23.36	23.04	13.48	13.80
744-0243	108.72	996.95	56.44	55.77	34.76	34.53	21.68	21.91
744-0245	2971.30	2791.22	50.27	49.20	23.41	22.74	26.86	27.53
744-0247	-587	3850	28.41	27.31	13.23	12.42	15.18	15.99
744-0254	446.00	4587.00	25.09	23.28	11.81	11.26	13.28	13.83
744-0255	1395.00	2547.46	39.73	34.23	21.63	21.71	18.10	18.02
744-0259	2908.50	3309.00	50.94	49.84	36.71	36.07	14.23	14.87
744-0266	3910.39	1317.63	69.19	67.39	51.11	51.11	18.08	18.08
744-0267	-1746.86	-3738.16	72.03	71.31	42.00	42.82	30.03	29.21
744-0268	2096.50	4482.81	32.69	31.56	DRY	NA	DRY	NA
744-0272	NA	NA	52.01	52.53	NA	NA	NA	NA
744-023D	-880	2026	63.71	63.71	44.45	NA	19.26	NA
744-024S	611.87	2278.72	61.25	60.42	42.24	42.04	19.01	19.21
744-025	406.70	2789.41	59.98	58.93	41.97	41.67	18.01	18.31
744-033	-1207	2864	44.70	44.70	28.11	27.89	16.59	16.81
744-041D	-1937	1176	64.91	64.91	44.45	43.50	20.46	21.41
744-044	-632	1640	66.82	66.82	44.87	44.47	21.95	22.35
744-045	143	2183	59.90	59.4	40.71	40.43	19.19	19.47

TABLE 4-21, continued

Selected Groundwater Elevation Data

Well Number	South Coordinate	East Coordinate	Top of Casing Elevation	Ground Surface Elevation	Depth to Groundwater (in feet) 19-Nov-85	Depth to Groundwater (in feet) 19-Feb-86	Groundwater Elevation (in feet) 19-Nov-85	Groundwater Elevation (in feet) 19-Feb-86
RI-1XD	3517.6	6155.32	24.18	22.70	12.84	12.46	11.34	11.72
RI-1D	3506.4	6159.05	24.70	23.20	14.72	14.67	9.98	10.03
RI-1S	3493.68	6163.27	24.75	22.80	15.01	15.62	9.74	9.13
RI-2XD	2793.1	6575.97	14.08	14.29	1.56	0.96	12.52	13.12
RI-2D	2793.26	6570.41	13.61	14.21	1.98	1.32	11.63	12.29
RI-2S	2787.92	6567.66	13.37	14.08	1.73	0.97	11.64	12.40
RI-3XD	2262	6983.91	19.92	20.12	3.97	5.41	15.95	14.51
RI-3D	2261.77	6975.85	20.19	20.21	5.14	4.16	15.05	16.03
RI-3S	2257.02	6980.43	20.18	20.32	5.12	4.19	15.06	15.99
RI-4S	2689.5	5373.78	48.90	49.10	37.12	36.85	11.78	12.05
RI-4D	2707.15	5380.82	49.18	49.40	37.27	36.94	11.91	12.24
RI-5S	2291.63	4921.84	39.54	39.95	26.84	26.37	12.70	13.17
RI-5D	2283.51	4908.45	39.54	39.88	26.78	26.41	12.76	13.13
RI-6	-636.01	4994.99	23.01	23.22	9.54	8.76	13.47	14.25
RI-7	-949.36	4480.92	18.44	18.76	4.99	4.56	13.45	13.88
RI-8	-1489.93	3799.9	22.24	22.46	7.47	6.67	14.77	15.57
RI-9	-1434.35	3109.95	20.89	21.18	6.32	5.95	14.57	14.94
RI-10D	-1511.22	4480.21	22.85	23.20	7.08	5.63	15.77	17.22
RI-10S	-1504.39	4483.02	22.88	23.12	7.19	5.61	15.69	17.27
RI-11S	-1241.88	4880.95	20.85	21.00	5.35	3.31	15.50	17.54
RI-11D	-1238.27	4890.02	19.80	21.18	4.27	2.43	15.53	17.37
RI-12S	2280.57	6154.51	17.12	17.26	6.48	6.03	10.64	11.09
RI-12D	2284.99	6158.23	17.02	17.23	5.09	4.48	11.93	12.54
RI-13S	1977.79	5925.35	13.20	13.49	2.14	1.80	11.06	11.40
RI-13D	1973.23	5922.95	13.33	13.63	0.86	0.27	12.47	13.06
RI-14S	1718.78	4433.36	35.95	36.00	NA	21.82	NA	14.13
RI-14D	1724.8	4434.32	35.96	36.09	22.33	21.89	13.63	14.07
RI-15S	1405.49	4165.62	48.00	48.15	33.28	32.84	14.72	15.16

TABLE 4-21, continued

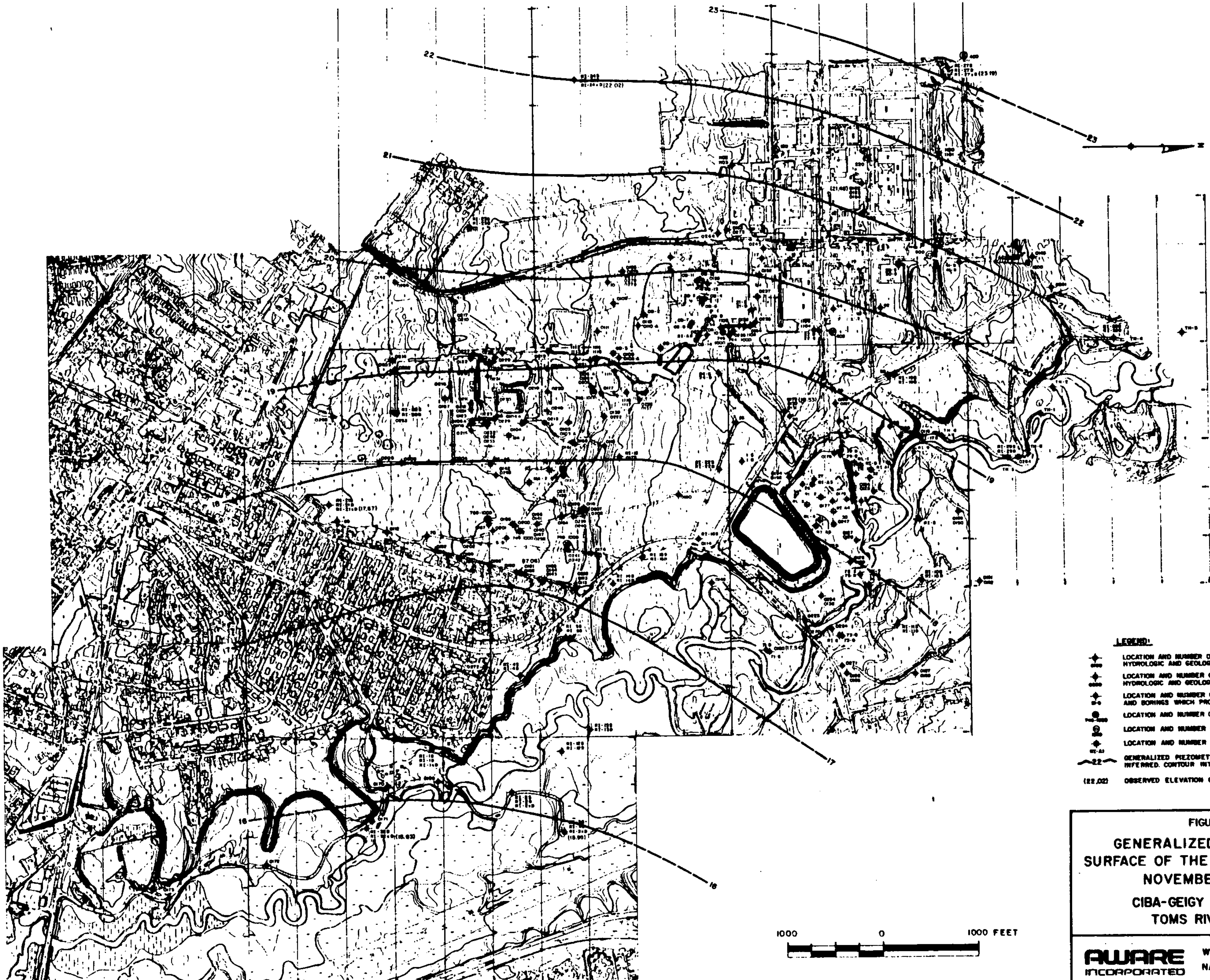
Selected Groundwater Elevation Data

Well Number	South Coordinate	East Coordinate	Top of Casing Elevation	Ground Surface Elevation	Depth to Groundwater (in feet)		Groundwater Elevation (in feet)	
					19-Nov-85	19-Feb-86	19-Nov-85	19-Feb-86
RI-15D	1399.28	4161.31	48.42	48.55	34.03	33.62	14.39	14.80
RI-16	815.81	3989.25	53.16	54.10	38.00	37.63	15.16	15.53
RI-17	-1494.02	2923.79	25.52	23.50	10.01	9.34	15.51	16.18
RI-18	1636.29	3127.04	41.54	39.80	24.81	24.49	16.73	17.05
RI-19S	-1240.02	2304.33	51.54	49.90	33.35	32.56	18.19	18.98
RI-19D	-1246.97	2300.92	51.42	49.90	33.28	32.45	18.14	18.97
RI-20S	3934.24	2673.68	55.49	53.97	39.43	39.52	16.06	15.97
RI-20D	3927.49	2676.14	55.65	54.07	39.64	39.72	16.01	15.93
RI-21XD	4638.6	3598.79	49.33	48.10	31.92	32.23	17.67	17.36
RI-21D	4637.05	3592.73	49.58	48.20	35.78	35.81	13.80	13.77
RI-21S	4635.41	3586.34	49.59	48.19	35.82	35.84	13.77	13.75
RI-22S	596.58	3275.8	56.67	55.10	39.71	39.35	16.96	17.32
RI-22D	598.36	3281.43	56.44	54.90	39.49	39.16	16.95	17.28
RI-23S	3175.69	745.96	66.96	65.53	47.63	47.64	19.33	19.32
RI-23D	3163.79	750.21	67.47	65.53	48.13	48.15	19.34	19.32
RI-24XD	2047.28	-768.17	67.16	65.79	45.14	44.93	22.02	22.23
RI-24D	2054.16	-767.47	67.40	65.79	44.39	44.15	23.01	23.25
RI-24S	2061.24	-768.04	67.17	65.59	44.31	44.09	22.86	23.08
RI-25	512.12	-2334.94	52.87	51.12	26.53	25.55	26.34	27.32
RI-26	-1483.78	-4528.07	74.49	73.00	42.54	43.23	31.95	31.26
RI-27XD	-1845.09	-845.72	61.08	59.90	37.89	37.01	23.19	24.07
RI-27D	-1852.46	-837.16	60.43	59.60	41.85	35.75	18.58	24.68
RI-27S	-1848.97	-841.31	61.39	59.80	39.93	36.72	21.46	24.67
RI-28S	-3550.34	1970.52	30.30	28.50	12.20	11.47	18.10	18.83
RI-28D	-3544.67	1973.56	30.15	28.80	12.07	11.33	18.08	18.82
RI-29S	-2526.38	3167.72	20.31	18.80	4.79	4.38	15.52	15.93
RI-29D	-2531.51	3164.91	20.28	18.80	4.42	3.87	15.86	16.41
RI-31S	-1865.59	2000.61	47.89	46.30	29.31	28.38	18.58	19.51
RI-31D	-1874.89	1994.79	47.85	46.70	29.48	28.57	18.37	19.28

TABLE 4-21, continued

Selected Groundwater Elevation Data

Well Number	South Coordinate	East Coordinate	Top of Casing Elevation	Ground Surface Elevation	Depth to Groundwater (in feet)		Groundwater Elevation (in feet)	
					19-Nov-85	19-Feb-86	19-Nov-85	19-Feb-86
RI-32XD	4279.03	6916.04	16.97	17.35	1.14	2.03	15.83	14.94
RI-32D	4285.15	6917.33	17.00	17.18	5.59	5.15	11.41	11.85
746-1000	1880.0	2470.0	45.48	NA	NA	NA	NA	NA
747-1000	2159.0	3231.6	45.95	NA	32.77	31.25	13.14	14.66
748-1000	2220.0	4020.0	40.82	NA	29.02	27.87	12.68	13.83
749-1000	2680.0	3895.0	57.12	NA	47.43	46.22	10.87	12.08
750-1000	3000.0	3760.0	61.68	NA	50.88	49.35	11.94	13.47



LEGEND:

- LOCATION AND NUMBER OF MONITORING WELLS WHICH PROVIDE HYDROLOGIC AND GEOLOGIC INFORMATION
- LOCATION AND NUMBER OF PIEZOMETERS, WHICH PROVIDE HYDROLOGIC AND GEOLOGIC INFORMATION
- LOCATION AND NUMBER OF MONITORING WELLS, PIEZOMETERS, AND BORINGS WHICH PROVIDE ONLY GEOLOGIC INFORMATION
- LOCATION AND NUMBER OF PURGE WELLS
- LOCATION AND NUMBER OF PRODUCTION WELLS
- LOCATION AND NUMBER OF AUGER BORINGS
- ~22~ GENERALIZED PIEZOMETRIC CONTOUR, IN FEET. DASHED WHERE INFERRED. CONTOUR INTERVAL IS ONE FOOT
- (22.02) OBSERVED ELEVATION OF PIEZOMETRIC SURFACE, IN FEET

FIGURE 4-41

GENERALIZED PIEZOMETRIC SURFACE OF THE KIRKWOOD #2 SAND NOVEMBER 19, 1985

CIBA-GEIGY CORPORATION
TOMS RIVER PLANT

AWARE INCORPORATED
WEST MILFORD, NEW JERSEY
NASHVILLE, TENNESSEE

River. This pattern suggests that some discharge of groundwater occurs from the Kirkwood No. 2 Sand to the Toms River.

The estimated effective hydraulic conductivity is on the order of 2.1 x 10^{-2} cm/sec (445 gpd/ft^2) for the Kirkwood No. 2 Sand. The estimated transmissivity of the Kirkwood No. 2 Sand water-bearing zone would be on the order of 4,450 gpd/ft.

Kirkwood No. 1 Sand Water-Bearing Zone

The Kirkwood No. 1 Sand water-bearing zone is contained within the lithostratigraphic unit of the same name. At this time only three monitoring wells have been installed in this water-bearing zone. As such, the data are not sufficient to allow preparation of groundwater contour maps. However one would anticipate groundwater flow patterns similar to those of the Primary Cohansey water-bearing zone, but somewhat more subdued and perhaps at a slightly lower elevation in recharge areas and slightly higher in discharge areas.

The estimated effective hydraulic conductivity of this unit is on the order of 1.5 x 10^{-2} cm/sec. The estimated transmissivity of the Kirkwood No. 1 Sand would be on the order of 8,000 gpd/ft.

Lower Cohansey Water-Bearing Zone

The Lower Cohansey sand unit has been defined as a separate water-bearing zone primarily on the basis of the distribution of contamination detected within this unit. There is virtually no hydraulic head difference between this unit and the overlying Primary Cohansey. However, since a distinct contaminant plume has been detected within the Lower Cohansey, a conceptual distinction has been made, largely for reasons of convenience.

One area in which a significant hydraulic distinction exists is at the discharge to the Toms River in the vicinity of monitoring well RI-9. It is evident that deep groundwater flow paths from the Lower Cohansey discharge to the north of the active channel of the river in this area as a result of the river's meander and the Cohansey/Kirkwood Transitional Unit's semi-confining properties.

As previously described, the Lower Cohansey sand is discontinuous across the plant site. To the east and southeast the unit thins and becomes progressively finer-grained. To the west and northwest, the Lower Cohansey thickens and becomes coarser-grained. Our interpretation of the data suggests that to the extreme west and northwest, the Lower and Primary Cohansey sands are in direct hydraulic communication and constitute a single hydraulic unit.

In the area of primary concern, the hydraulic conductivity of the Lower Cohansey is essentially the same as the Primary Cohansey. An aquifer test performed in 1956 by the Ranney Method Water Supply Company indicated an hydraulic conductivity of 830 gpd/ft^2 (3.9 x 10^{-2} cm/sec) for the Lower Cohansey. With a typical thickness of 25 to 30 feet in this area, the transmissivity would be on the order of 20,750 gpd/ft to 24,900 gpd/ft.

Primary Cohansey Water-Bearing Zone

The Primary Cohansey Water-Bearing Zone is the thickest and most areally extensive of the various water-bearing zones. It is also the water-bearing zone that contains the highest levels of contamination and in which the major contaminant plumes are migrating. At the time of this report a total of 86 monitoring wells and piezometers had been installed within the Primary Cohansey and could be used to generate groundwater contour maps. Figure 4-42 illustrates the configuration of hydraulic head within the Primary Cohansey on November 19, 1985.

The groundwater contour map indicates that groundwater flow within the Primary Cohansey is primarily in an east-northeastward direction towards the Toms River from the south side of the river and to the southwestward towards the river from the north side of the river. This pattern of groundwater flow indicates that the Toms River is the major discharge zone for the Primary Cohansey. A depression of the potentimoetric surface is evident on Figure 4-42 and marks the presence of three of the five purge wells that constitute the "Cardinal Drive Purge Well System". Discharge to the purge well system is on the order of 360,000 gallons per day (250gpm). The impact of this system is further discussed in Section 4.4.2.

The aquifer tests of the Cohansey Formation described in Section 4.3.3 indicated transmissivities ranging from 22,300 gpd/ft to 94,000 gpd/ft (2.8×10^{-2} cm/sec). In consideration of all of the data, it is concluded that the hydraulic conductivity of the Primary Cohansey is most likely in the range of 850 gpd/ft^2 (4.0×10^{-2} cm/sec) to 1060 gpd/ft^2 (5.0×10^{-2} cm/sec).

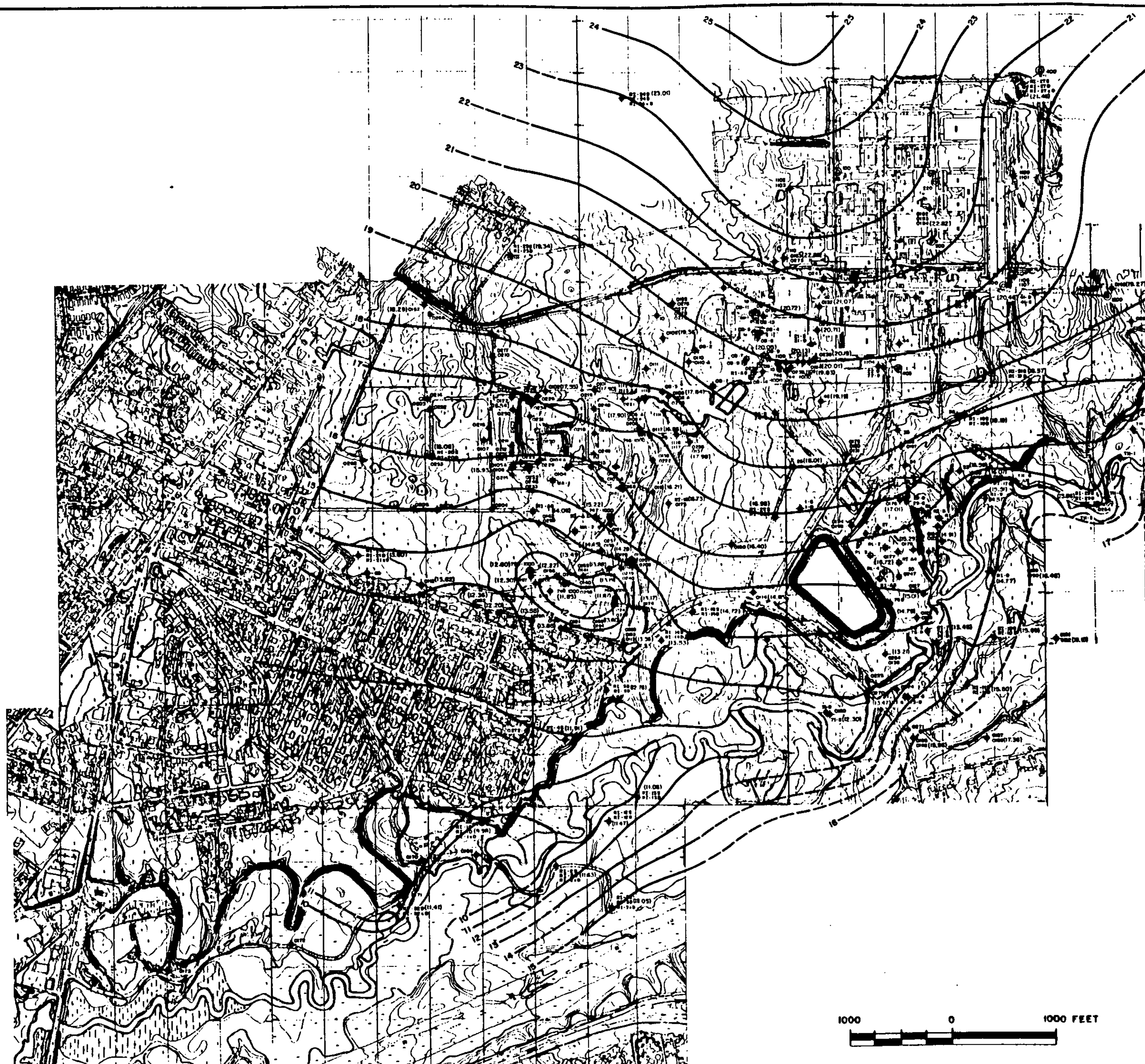
Figure 4-43 represents the differential head between the Primary Cohansey and Kirkwood No. 2 water-bearing zones on November 19, 1985. The differential head map illustrates the location of the boundary between vertically downward flow from the Primary Cohansey to the Kirkwood and vertically upward flow from the Kirkwood to the Cohansey. Not surprisingly, the flow components are upward as one approaches the Toms River and are downward as one moves further away from the river. The maps indicate, as well, that a substantial portion of the Toms River Plant site, including several of the actual or potential contaminant source areas, is located in the discharge area of the Kirkwood No.2 water-bearing zone. Accordingly, downward movement of contaminants below the Primary Cohansey in these areas is unlikely.

Groundwater Flow and Seepage Velocity Estimates

Data regarding the hydraulic conductivities of the various hydrostratigraphic units can be integrated with observed hydraulic gradients derived from the groundwater contour maps to provide estimates of volumetric flow rates and seepage velocities. The likely range of groundwater seepage velocities in the Primary Cohansey has been calculated using the relation:

$$V_s = ki/n_e$$

Where:
- V_s = seepage velocity (l/t)
- k = hydraulic conductivity (l/t)
- i = hydraulic gradient (l/l)
- n_e = effective porosity (dimensionless)



LEGEND:

- LOCATION AND NUMBER OF MONITORING WELLS WHICH PROVIDE HYDROLOGIC AND GEOLOGIC INFORMATION
- LOCATION AND NUMBER OF PIEZOMETERS WHICH PROVIDE HYDROLOGIC AND GEOLOGIC INFORMATION
- LOCATION AND NUMBER OF MONITORING WELLS, PIEZOMETERS, AND BORINGS WHICH PROVIDE ONLY GEOLOGIC INFORMATION
- LOCATION AND NUMBER OF PURGE WELLS
- LOCATION AND NUMBER OF PRODUCTION WELLS
- LOCATION AND NUMBER OF AUGER BORINGS
- 15 — GENERALIZED POTENTIOMETRIC CONTOUR, IN FEET. DASHED WHERE INFERRED. CONTOUR INTERVAL IS ONE FOOT
- (14.85) OBSERVED ELEVATION OF POTENTIOMETRIC SURFACE, IN FEET

FIGURE 4-42

GENERALIZED POTENTIOMETRIC SURFACE OF THE PRIMARY COHANSEY NOVEMBER 19, 1985

CIBA-GEIGY CORPORATION TOMS RIVER PLANT

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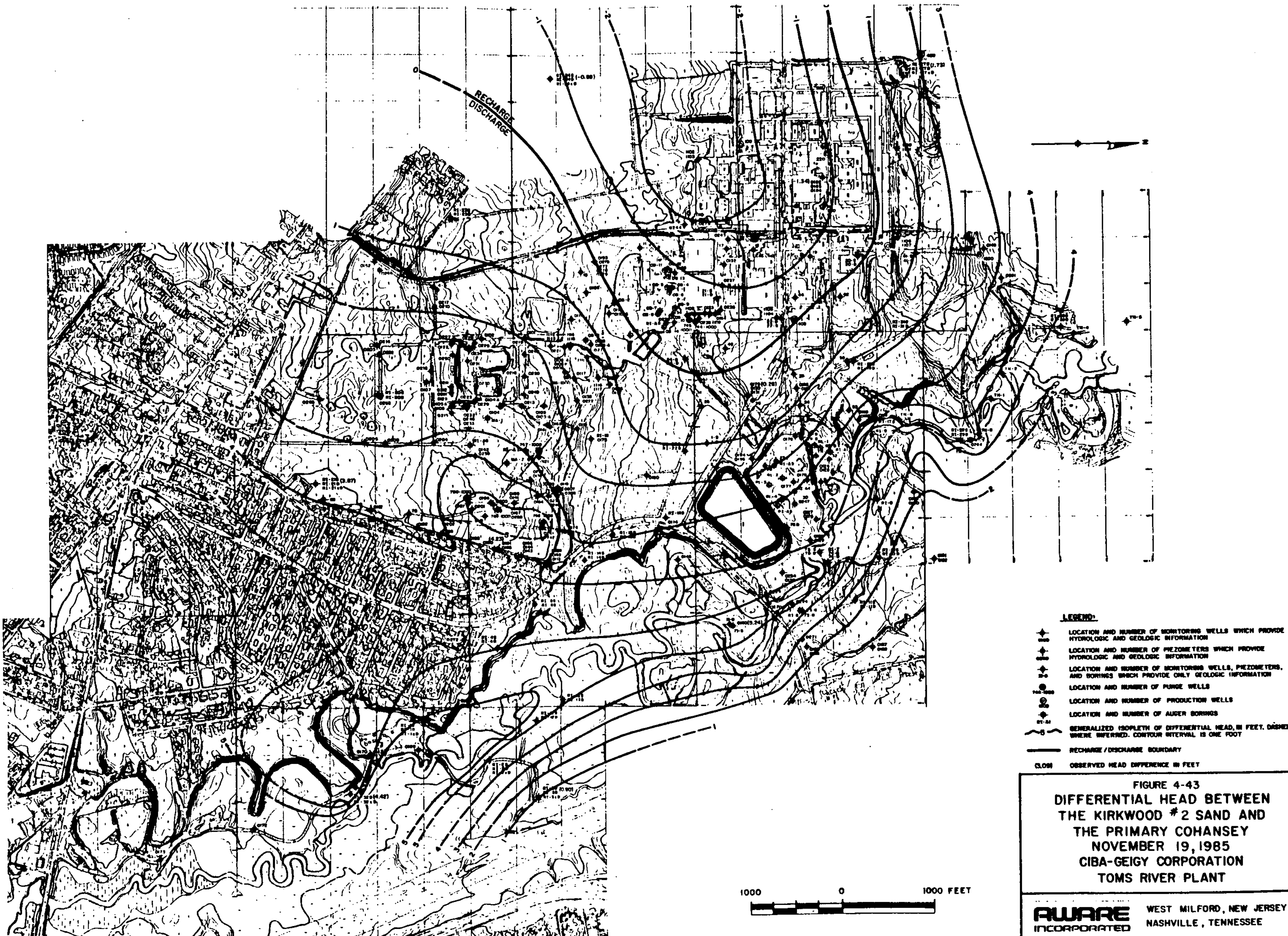


FIGURE 4-43
DIFFERENTIAL HEAD BETWEEN THE KIRKWOOD #2 SAND AND THE PRIMARY COHANSEY
NOVEMBER 19, 1985
CIBA-GEIGY CORPORATION
TOMS RIVER PLANT

AWARE INCORPORATED
WEST MILFORD, NEW JERSEY
NASHVILLE, TENNESSEE

The hydraulic gradient term is provided by the groundwater contour maps for the Primary Cohansey aquifer and is typically on the order of 0.003. The effective porosity is estimated to be 0.30. The estimated hydraulic conductivity is on the order of 4.5×10^{-2} cm/sec (127 ft/day). The estimated seepage velocity in the Primary Cohansey is approximately 1.27 feet per day. Seepage velocities within the Lower Cohansey would be expected to be of the same magnitude.

Volumetric flow rates in the Primary Cohansey can be estimated using Darcy's Law:

$$Q = kiA$$

Where: Q = the volumetric flow rate (l^3/t)
k = hydraulic conductivity (l/t)
i = hydraulic gradient (dimensionless)
A = cross-sectional area through which flow occurs (l^2)

At an hydraulic conductivity of 4.5×10^{-2} cm/sec (955 gpd/ft^2), a typical hydraulic gradient of 0.003, and a unit area, the volumetric flow rate in the Primary Cohansey is on the order of 2.8 gpd per square foot of cross-sectional area of the aquifer.

Table 4-22 presents a gross water balance for the Toms River Plant site. In the water balance the hydraulic conductivity of the Primary Cohansey is as previously described. The vertical hydraulic conductivity for the Kirkwood was determined as the harmonic mean of the hydraulic conductivities and thicknesses of the Primary Kirkwood, the Kirkwood No. 1 Sand, and the Upper Kirkwood. The hydraulic conductivities used were as previously described; the thicknesses used were 40 feet, 18 feet, and 42 feet, respectively. Cross-sectional areas of inflow and outflow were estimated from the groundwater contour map using a typical saturated thickness of 35 feet for the Primary Cohansey. Areas of recharge and discharge were estimated using the differential head map.

The water balance is presented simply as an accounting of the relative amounts of groundwater recharge and discharge from the various sources and sinks. It may be used also as a preliminary bench mark against which to compare the results of computer simulations of groundwater flow.

4.4.2 Groundwater Quality

Groundwater quality impacts have been identified only within the water-bearing zones contained within the Cohansey Formation, namely, the Upper, Primary, and Lower Cohansey water-bearing zones; to date there has been no evidence of degradation in either the Kirkwood No. 1 or No. 2 sands. Within the Cohansey, the Primary Cohansey water-bearing zone clearly exhibits the most widespread plume, although locally both the Upper and Lower water-bearing zones are contaminated.

A variety of contaminants or indicators of contamination have been detected within the Cohansey, including both inorganic and organic constituents. The former include elevated chloride and sulfate, as well as elevated total dissolved solids (TDS) and specific conductance. The latter include both

TABLE 4-22

WATER BALANCE FOR THE
COHANSEY FORMATION ON THE
TOMS RIVER PLANT SITE

HORIZONTAL K (Primary Cohansey)	4.5E-02 cm/sec	1.27E+02 ft/day
VERTICAL K (Composite Kirkwood)	2.4E-05 cm/sec	6.8E-02 ft/day
GRADIENT (LATERAL)	0.003	
GRADIENT (VERTICAL)	0.02 (DOWN)	0.03 (UP)
X-SECTIONAL AREA (INFLOW)	280,000 sq. ft.	
X-SECTIONAL AREA (OUTFLOW)	400,000 sq. ft.	
SURFACE AREA (Kw>Coh)	2.9E+07 sq. ft.	
SURFACE AREA (Coh>Kw)	1.2E+07 sq. ft.	
RECHARGE (INFILTRATION)	24 in/yr	5.5E-03 ft/day
RECHARE (AREA)		4.1E+07 sq. ft.

SOURCES	SINKS
Areal Recharge	**Wells**
Q_R = RECHARGE X AREA 1.68E+06 gallons/day	1.7E+06 gallons/day
Groundwater Inflow from Upgradient	**Groundwater To Toms River**
Q_I = kiA 7.97E+05 gallons/day	1.14E+06 gallons/day
Recharge from Kirkwood	**Discharge to Kirkwood**
Q_{Kw} = kiA 4.37E+05 gallons/day	1.26E+05 gallons/day
Sum of Sources	**Sum of Sinks**
2.91E+06 gallons/day	2.97E+06 gallons/day

Sum of Sources/Sum of Sinks 98.14%

volatile and base/neutral extractable organic compounds. The acid extractable organic fraction is apparently not particularly significant at this site.

Inorganic Compounds

The primary type of groundwater contamination at the Toms River Plant is by volatile and base/neutral extractable compounds. However, a suite of inorganic contamination is also associated with the known contaminant plume. The inorganic suite is marked by elevated chloride, sulfate, sodium and potassium as well as by elevated iron, manganese, and calcium. The combined effects of the various inorganic constituents are reflected in significantly elevated total dissolved solids and specific conductance. This relationship is fortuitous since it permits delineation of the extent of contamination with methods that rely upon a contrast in electrical conductivity, such as terrain conductivity or resistivity. Figure 4-44, provides the results of the terrain conductivity method. Figure 4-45, an isoconcentration map of chlorides, is remarkably similar to the terrain conductivity isopleth map and illustrates the extent of elevated chloride in the Primary Cohansey. Chloride is typically considered a conservative, non-reactive constituent that serves as an excellent indicator of the leading edge of contamination.

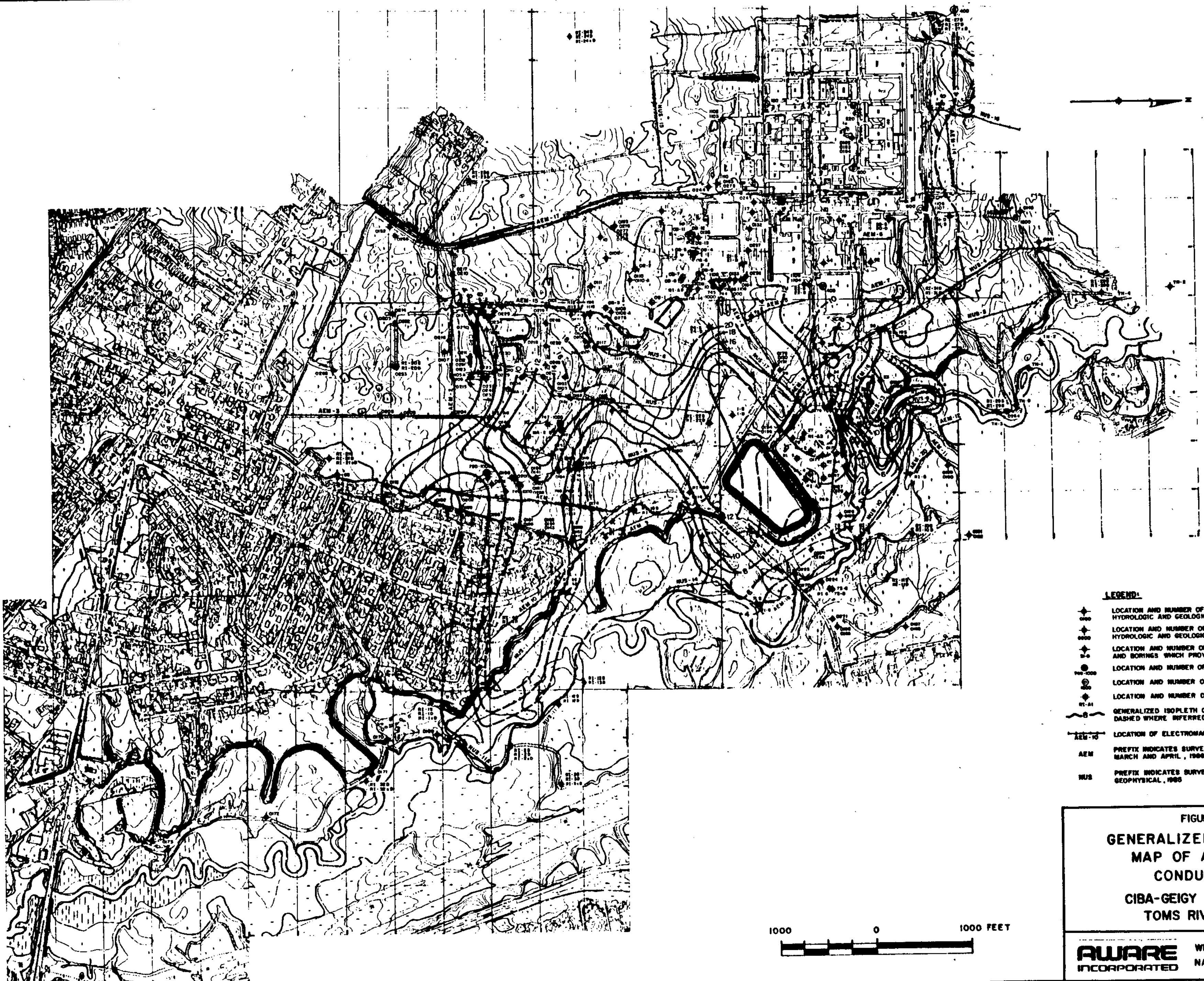
Organic Compounds

A varied and extensive suite of organic compounds has been detected in the groundwater beneath the plant site. The organic suite consists largely of volatile organic solvents, in particular chlorobenzene and related compounds, as well as numerous base/neutral extractable compounds. A lesser suite of acid extractable compounds has been detected in a limited number of monitoring wells.

The discussion that follows is based largely upon analytical data obtained during the Remedial Investigation. Analyses of samples collected from existing Ciba-Geigy monitoring wells by SR Analytical of Cherry Hill, New Jersey are summarized on Tables 4-23 and 4-24. In addition, analyses of samples obtained from the RI-series monitoring wells and from selected Ciba-Geigy monitoring wells are presented on Table 4-25. The latter analyses, performed by JTC Environmental Consultants, Inc. of Rockville, Maryland, represent the results of a split-sampling effort conducted by Ciba-Geigy and USEPA/NUS. The actual data reports from SR Analytical, JTC, and the USEPA contract laboratory are included in Volume V of this document. The data reports for analysis performed on irrigation well samples from the Oak Ridge Subdivision area are also included in Volume V.

Volatile Organic Constituents

Volatile organic compounds are by far the most prevalent constituents detected in the groundwater system at the Toms River Plant. The volatile suite includes the following compounds that are routinely detected at significant concentrations:



LEGEND:

- LOCATION AND NUMBER OF MONITORING WELLS WHICH PROVIDE HYDROLOGIC AND GEOLOGIC INFORMATION
- LOCATION AND NUMBER OF PIEZOMETERS WHICH PROVIDE HYDROLOGIC AND GEOLOGIC INFORMATION
- LOCATION AND NUMBER OF MONITORING WELLS, PIEZOMETERS, AND BORINGS WHICH PROVIDE ONLY GEOLOGIC INFORMATION
- LOCATION AND NUMBER OF PURGE WELLS
- LOCATION AND NUMBER OF PRODUCTION WELLS
- LOCATION AND NUMBER OF AUGER BORINGS
- GENERALIZED ISOPLETH OF APPARENT CONDUCTANCE, IN mho/m. DASHED WHERE INFERRED. CONTOUR INTERVAL IS 2 mho/m
- AEM-10 LOCATION OF ELECTROMAGNETIC SURVEY LINE
- AEM PREFIX INDICATES SURVEY CONDUCTED BY AWARE, INC. MARCH AND APRIL, 1986
- NUS PREFIX INDICATES SURVEY CONDUCTED BY WESTON GEOPHYSICAL, 1985

1000 0 1000 FEET

FIGURE 4-44

GENERALIZED ISOPLETH MAP OF APPARENT CONDUCTIVITY

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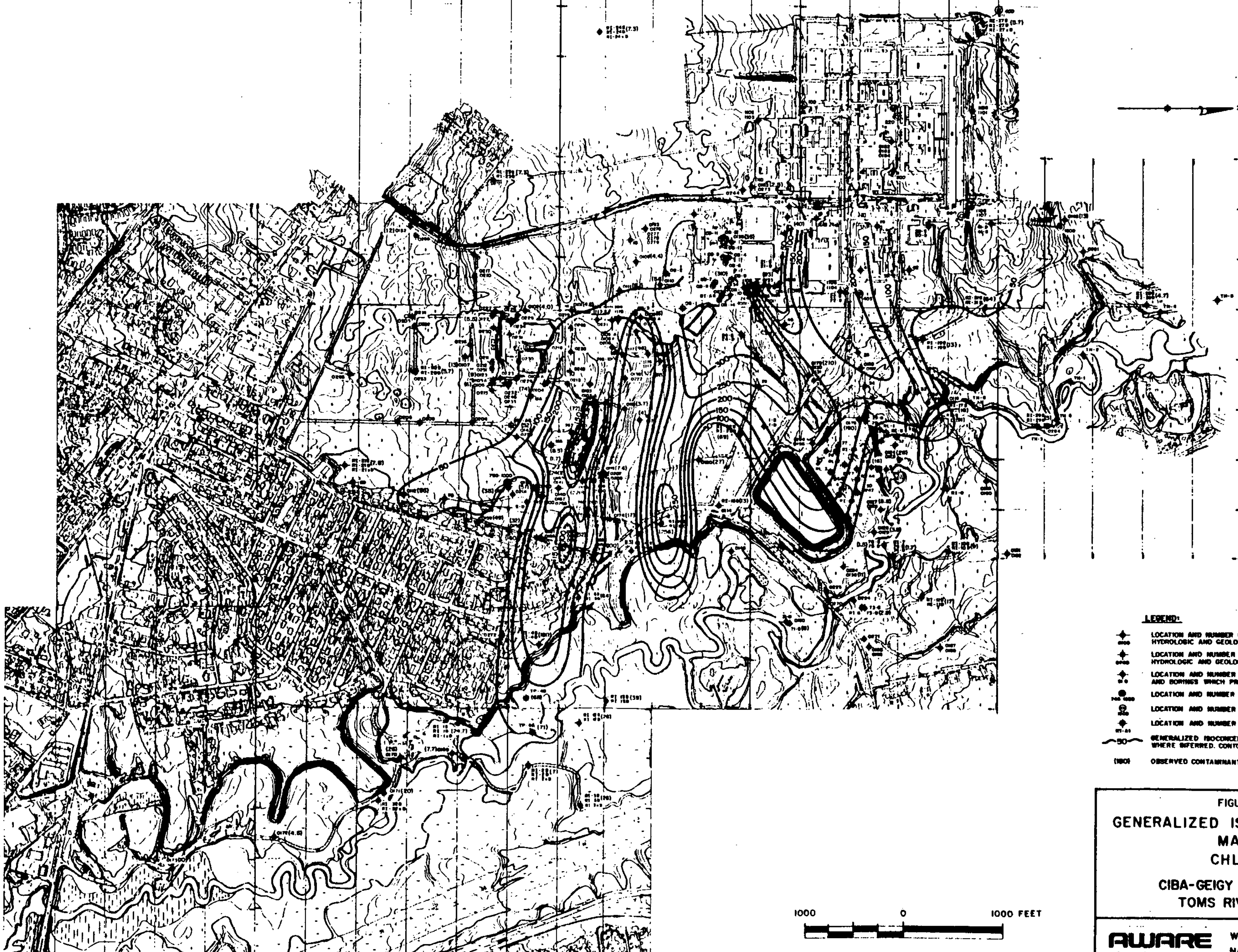
TOMS RIVER PLANT

AWARE INCORPORATED
WEST MILFORD, NEW JERSEY
NASHVILLE, TENNESSEE



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- LOCATION AND NUMBER OF PURGE WELLS
- LOCATION AND NUMBER OF PRODUCTION WELLS
- LOCATION AND NUMBER OF AUGER BORINGS
- ~50~ GENERALIZED ISOCONCENTRATION CONTOUR, IN PPB. DASHED WHERE INFERRED. CONTOUR INTERVAL IS VARIABLE
- (180) OBSERVED CONTAMINANT CONCENTRATION IN PPB

FIGURE 4-45

GENERALIZED ISOCONCENTRATION MAP OF CHLORIDE

CIBA-GEIGY CORPORATION TOMS RIVER PLANT

AWARE INCORPORATED

WEST MILFORD, NEW JERSEY
NASHVILLE, TENNESSEE

CIB 004 1974

SUMMARY OF SR ANALYTICAL DATA
SEPTEMBER 10-18, 1985

WELL NO.	BENZENE	CHLORO BENZENE	TRI CHLOROETHENE	1,1,1-TRI CHLOROETHANE	1,2-DI CHLOROETHANE	CHLOROFORM	TRANS-1,2 DI CHLOROETHENE	ETHYL BENZENE	TETRA CHLOROETHENE	TOLUENE	METHYLENE CHLORIDE	1,2- DI CHLOROBENZENE	NITRO BENZENE	NAPHTHALENE	SULFATE	CHLORIDE
101	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	9.0	4.6
102	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	5.1	19	ND	5.2	4.0
103	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	26.0	11.0
104	190	690	270	ND	ND	ND	ND	ND	190	ND	ND	200	ND	13	110.0	74.0
105	11	93	17	ND	ND	ND	ND	17	30	81	ND	ND	ND	ND	20.0	6.0
106	ND	15	ND	ND	ND	ND	ND	ND	20	ND	ND	ND	ND	ND	17.0	4.8
107	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	10.0	13.0
108	16	14	ND	ND	ND	ND	ND	ND	89	ND	ND	ND	ND	ND	140.0	6.0
109	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	5.8	4.4
110	ND	ND	ND	ND	ND	ND	14	ND	ND	ND	ND	ND	ND	ND	24.0	5.6
111	2400	8400	800	ND	ND	1400	170	1700	6000	14000	ND	3800	15000	110	81.0	8.1
112	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	49.0	55.0
113	ND	24	ND	ND	ND	47	ND	ND	ND	ND	ND	2.0	ND	ND	440.0	100.0
114	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	11.0	4.7
115	110	450	25000	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	510.0	62.0
117	ND	1800	ND	ND	ND	ND	ND	ND	ND	ND	ND	1300	ND	5.5	140.0	96.0
118	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	8.0	3.7
119	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	20.0	7.4
121	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	59	ND	28	10.0	8.5
122	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	6.3	5.5
123	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	8.6	9.0
124	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	89	ND	86	160.0	28.0
125	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	380.0	67.0
126	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	30.0	8.8
127	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	170.0	28.0
128	ND	110	ND	ND	ND	ND	ND	ND	ND	ND	ND	37	ND	ND	37.0	46.0
129	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	8.7	3.9
131	ND	3500	1600	ND	ND	16	ND	ND	2700	870	ND	2300	7200	130	470.0	210.0
132	ND	ND	1200	60	22	ND	13	ND	ND	ND	ND	380	160	3.1	64.0	40.0
133	ND	8300	ND	ND	ND	ND	ND	ND	12000	2800	ND	10000	39000	630	350.0	93.0
134	ND	1600	2000	ND	ND	ND	750	ND	1900	630	ND	3000	3500	150	300.0	310.0
135	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	76.0	35.0
136	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	8.7	11.0
137	ND	8700	ND	ND	ND	ND	ND	ND	ND	ND	ND	3400	ND	630	190.0	65.0
138	ND	20	ND	ND	ND	ND	ND	ND	34	ND	ND	ND	ND	ND	66.0	32.0
139	ND	440	25	ND	ND	54	43	ND	ND	ND	ND	190	ND	5.2	670.0	1.9
140	ND	26000	ND	ND	ND	ND	ND	ND	ND	ND	ND	190	ND	920	2400.0	180.0
141	ND	14000	ND	ND	ND	ND	ND	ND	ND	ND	ND	76	ND	460	2000.0	200.0
142	33	94	46	ND	ND	ND	ND	ND	44	ND	ND	21	ND	ND	120.0	52.0
143	ND	56	ND	ND	ND	28	ND	ND	53	ND	ND	18	ND	ND	210.0	23.0
144	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	26.0	4.9
146	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	12.0	13.0
150	16	1500	42	ND	ND	ND	120	ND	33	ND	10	73	ND	18	660.0	160.0
151	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	8.4	4.1
152	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	12.0
153	ND	ND	ND	ND	ND	11	ND	ND	ND	ND	15	ND	ND	ND	24.0	6.2
154	27	2000	ND	ND	ND	ND	ND	ND	ND	ND	ND	760	ND	ND	720.0	220.0
155	27	9500	ND	ND	ND	ND	160	330	ND	18	ND	140	ND	270	1800.0	240.0
156	220	530	300	ND	ND	ND	ND	ND	ND	ND	14	230	ND	17	140.0	57.0
157	120	100	ND	ND	ND	ND	ND	ND	ND	ND	27	71	ND	4.7	43.0	35.0
158	156	170	31	ND	ND	26	ND	ND	79	ND	ND	55	ND	2.9	130.0	32.0

TABLE 4-23, Continued

SUMMARY OF SR ANALYTICAL DATA
SEPTEMBER 10-18, 1985

WELL NO.	BENZENE	CHLORO BENZENE	TRI CHLOROETHENE	1,1,1-TRI CHLOROETHANE	1,2-DI CHLOROETHANE	CHLOROFORM	TRANS-1,2 DI CHLOROETHENE	ETHYL BENZENE	TETRA CHLOROETHENE	TOLUENE	METHYLENE CHLORIDE	1,2- DI CHLOROBENZENE	NITRO BENZENE	NAPHTHALENE	SULFATE	CHLORIDE
159	26	70	8	ND	ND	ND	ND	ND	29	ND	ND	82	ND	ND	83.0	49.0
160	ND	20	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	72.0	27.0
161	ND	390	240	ND	ND	ND	140	ND	260	ND	ND	220	ND	ND	340.0	72.0
162	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	170.0	39.0
163	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	2.5
164	ND	ND	870	ND	ND	51	71	ND	3200	110	ND	350	930	12	98.0	39.0
165	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	4.2
166	ND	260	ND	ND	ND	35	30	ND	43	ND	ND	180	ND	8.0	600.0	52.0
167	ND	93	ND	ND	ND	ND	ND	ND	ND	ND	10	ND	ND	ND	660.0	120.0
168	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	10	ND	ND	12.0	4.0
169	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	16.0	7.7
170	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	11.0	26.0
171	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	13.0	20.0
172	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	8.7	4.5
173	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	17.0	10.0
174	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	69.0	17.0
175	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	5.7	4.0
71S	ND	22	10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	37.0	3.8
71D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	24.0	8.0
73S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	5.8
73D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	9.3	2.9
74S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	15	ND	ND	ND	ND	6.3
74D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	5.3	1.7
75S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	6.4	2.7
75D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.5
TP4-A	110	1200	930	ND	ND	240	71	ND	130	ND	10	34	ND	6.9	410.0	71.0
TP4-B	110	1600	1800	ND	ND	50	190	ND	180	ND	11	70	ND	6.3	380.0	68.0

TABLE 4-24

SUPPLEMENTAL GROUNDWATER ANALYSES

SUMMARY OF SR ANALYTICAL DATA
(APRIL 9-11, 1986)

PLANT PERIMETER WELLS

COMPOUND	744-1100	744-1101	744-1102	744-1103	744-1104	744-1105	744-1106	744-1107
Methylene Chloride	2.9B	2.9B	43B	42B	130	120	2.8B	2.9B
Trans-1,2-Dichloroethene	ND	ND	ND	ND	220	ND	ND	ND
Trichloroethene	0.5B	0.43B	1.4	1	15000	ND	6.6	0.37
Benzene	ND	ND	0.38	1.1	ND	150	0.74	0.24
Tetrachloroethene	ND	ND	ND	ND	ND	ND	10	ND
Toluene	3.4B	3.9B	3.2B	3.4B	140	160	4	ND
Chlorobenzene	ND	ND	ND	ND	820	1900	ND	ND
Chloroform	ND	ND	ND	0.73	ND	ND	10	0.55
1,1,2,2-Tetrachloroethane	1.6	ND	1.9	ND	ND	ND	3	ND
Di-N-Butyl Pthalate	4.3	ND	ND	ND	ND	ND	ND	ND
Nitrobenzene	ND	ND	ND	ND	2700	ND	ND	ND
1,2-Dichlorobenzene	ND	ND	ND	ND	11	190	ND	ND
Napthalene	ND	ND	ND	ND	ND	390	ND	ND

NOTES: 1. Even-numbered plant perimeter wells are screened in the Lower Cohansey.

2. Odd-numbered plant perimeter wells are screened in the Primary Cohansey.

3. Analyses are reported in ug/l.

4. "B" indicates probable laboratory contamination.

TABLE 4-24, continued

	RCRA Groundwater Assessment Wells						Kirkwood No. 1 Sand Wells		
COMPOUND	744-0194	744-0195	744-0196	744-0197	744-0198	744-0199	744-1108	744-1109	744-1110
Trans-1,2-Dichloroethene	12	1.0	600	330	3.9	30	ND	ND	ND
Trichloroethene	ND	26	2900	130	260	310	ND	ND	ND
Benzene	11	ND	320	63	18	18	ND	ND	ND
Tetrachloroethene	4.4	57	380	200	6.7	11	ND	ND	ND
Toluene	ND	7.4	14	ND	ND	ND	ND	ND	ND
Chlorobenzene	ND	58	150	480	19	29	ND	ND	ND
Chloroform	ND	1.5	ND	ND	1.4	11	ND	ND	ND
Di-N-Butyl Pthalate	60	40	75	105	105	140	ND	ND	ND
Di-Ethyl Pthalate	ND	ND	ND	ND	10	ND	ND	ND	ND
Mono-chlorobenzene	ND	25	70	ND	ND	ND	ND	ND	ND
Nitrobenzene	10	223	ND	40	ND	ND	ND	ND	ND
Napthalene	ND	ND	20	30	ND	10	ND	ND	ND
Pyrene	35	ND	25	30	85	40	ND	ND	ND
1,2-Dichlorobenzene	ND	25	40	130	ND	20	ND	ND	ND
1,3-Dichlorobenzene	ND	ND	ND	10	ND	ND	ND	ND	ND
1,4-Dichlorobenzene	ND	ND	ND	40	ND	ND	ND	ND	ND
1,2,4-Trichlorobenzene	ND	15	ND	20	ND	20	ND	ND	ND
Hexachlorobenzene	10	ND	ND	15	ND	10	ND	ND	ND
Hexachlorobutadiene	ND	ND	20	25	ND	ND	ND	ND	ND
Ortho-Chloro Toluene	ND	ND	ND	10	ND	10	ND	ND	ND
Isophorone	ND	ND	ND	10	ND	ND	ND	ND	ND
Benzo-a-anthracene	ND	ND	ND	ND	30	ND	ND	ND	ND
Bis-2-Chloro-Ethoxy-Methanol	ND	10	ND	240	ND	ND	ND	ND	ND

NOTES: 1. Even-numbered wells are screened in the Lower Cohansey.

2. Odd-numbered wells are screened in the Primary Cohansey.

3. Wells 744-1108, 744-1109, and 744-1110 are screened in the Kirkwood #1 Sand.

4. Analyses are reported in ug/1.

5. Analyses for RCRA Assessment wells performed by Ciba-Geigy.

TABLE 4-25

SUMMARY OF JTC ANALYTICAL DATA
AUGUST AND OCTOBER 1985

	VOLATILE ORGANIC COMPOUNDS														
WELL NO.	BENZENE	BROMOFORM	CHLORO BENZENE	TRI CHLORO ETHENE	1,2-DI CHLORO ETHANE	CHLORO FORM	TRANS-1,2 DICHLORO ETHENE	ETHYL BENZENE	TETRA CHLORO ETHENE	TOLUENE	METHYLENE CHLORIDE	1,1-DI CHLORO ETHANE	1,1,2,2 TETRA CHLOROETHANE	1,1,1-TRI CHLORO ETHANE	ACETONE
RI-1S	ND	ND	ND	ND	ND	(2)	ND	ND	ND	ND	ND	ND	ND	ND	68
RI-1D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	12
RI-1XD	ND	ND	ND	ND	ND	ND	ND	ND	ND	14	9	ND	ND	ND	5
RI-2S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-2D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	88
RI-2XD	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	10
RI-3S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	23
RI-3D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-3XD	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	130
RI-4S	ND	ND	54	6	ND	ND	74	ND	ND	ND	ND	ND	ND	ND	ND
RI-4D	18	ND	2740	ND	ND	ND	725	ND	18	27	ND	ND	ND	ND	14
RI-5S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-5S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-5D	11	ND	350	104	ND	91	59	ND	122	(4)	ND	ND	ND	ND	ND
RI-6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-8	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-9	76	ND	1680	8400	ND	ND	580	ND	ND	(4)	ND	ND	ND	ND	ND
RI-10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-10XD	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	44
RI-11	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-11XD	ND	ND	ND	ND	ND	ND	(2)	ND	ND	ND	ND	ND	ND	ND	56
RI-12S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	24
RI-12D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	197
RI-13S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-13D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-14S	ND	ND	ND	ND	ND	(3)	ND	ND	ND	7	ND	ND	ND	ND	ND
RI-14D	ND	ND	ND	ND	ND	(4)	ND	ND	ND	13	ND	ND	ND	ND	ND
RI-15S	ND	ND	ND	ND	ND	(2)	ND	ND	ND	8	ND	ND	ND	ND	ND
RI-15D	11	ND	179	61	(3)	52	34	ND	22	10	ND	ND	ND	ND	(4)
RI-16	ND	ND	(4)	8	ND	ND	ND	ND	(3)	ND	ND	ND	ND	ND	21
RI-16	ND	ND	(4)	8	ND	ND	ND	ND	(3)	ND	ND	ND	ND	ND	21
RI-17	11	ND	67	415	ND	ND	14	ND	ND	ND	ND	ND	ND	ND	ND
RI-17	12	ND	78	415	ND	ND	14	ND	ND	ND	ND	ND	ND	ND	ND
RI-18	(2)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	(3)	ND
RI-19S	ND	ND	ND	ND	ND	ND	ND	ND	ND	5	ND	ND	ND	ND	15
RI-19D	ND	ND	ND	ND	ND	ND	ND	ND	ND	5	ND	ND	ND	ND	525
RI-20S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	960
RI-20S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	900
RI-20D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	370
RI-21S	ND	ND	ND	ND	ND	(4)	ND	ND	ND	ND	ND	ND	ND	ND	70
RI-21D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	3290
RI-21XD	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	36
RI-22S	ND	ND	ND	(2)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	38
RI-22D	ND	ND	9	47	ND	ND	(4)	ND	182	ND	ND	ND	ND	ND	300
RI-23S	ND	ND	ND	ND	ND	(3)	ND	ND	ND	ND	ND	ND	ND	ND	345
RI-23D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	4250
RI-24S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	115
RI-24D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	22000
RI-24XD	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	24500
RI-25	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	3440
RI-25	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	3870
RI-26	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	2540
RI-27S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	664
RI-27D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	3350
RI-27XD	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1590
RI-28S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	23
RI-28D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	264
RI-29S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	6
RI-29D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	65
RI-31S	ND	(2)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	50
RI-31D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-32D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	176
RI-32XD	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	2250
744-0115	660	ND	334	19500	ND	ND	135	ND	ND	(5)	ND	21	10	ND	30
744-0115	ND	ND	337	22000	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
744-0131	24	ND	2900	896	ND	16	14	14	2200	475	ND	ND	ND	ND	800
744-0174	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
744-0175	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	(4)	ND
744-0176	ND	ND	(4)	44	ND	ND	32	ND	12	ND	ND	ND	ND	ND	ND
744-0179	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	20
744-0181	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	250

NOTES: 1. ND indicates below method detection limits (see JTC reports dated 10/2/85 and 12/12/85 for detection limits).

2. Values reported in parentheses were detected at concentrations that are below the detection limit (see JTC reports dated 10/2/85 and 12/12/85 for detection limits).

3. NF indicates not found. For tentatively identified volatile organic compounds, the reported values are estimated concentrations.

4. All values are reported in ug/l, unless otherwise noted.

TABLE 4-25, continued

SUMMARY OF JTC ANALYTICAL DATA
AUGUST AND OCTOBER 1985

WELL NO.	VOLATILE ORGANICS, CONT'D: 1,2-DICHLOROPROPANE	VINYL CHLORIDE	CARBON DISULFIDE	XYLENES	TENTATIVELY IDENTIFIED VOLATILE COMPOUNDS: CHLOROPROPENE	METHYL PROPANOL	PENTANOL	TETRAHYDROFURAN	TRICHLOROPROPANE	TRIMETHYLPENTENE
RI-1S	ND	ND	ND	ND	NF	NF	NF	NF	NF	NF
RI-1D	ND	ND	ND	ND	NF	NF	NF	NF	NF	NF
RI-1XD	ND	ND	ND	ND	NF	NF	NF	NF	NF	NF
RI-2S	ND	ND	5	ND	NF	NF	NF	NF	NF	NF
RI-2D	ND	ND	ND	ND	NF	NF	NF	NF	NF	NF
RI-2XD	ND	ND	ND	ND	NF	NF	NF	NF	NF	NF
RI-3S	ND	ND	ND	ND	NF	NF	NF	NF	NF	NF
RI-3D	ND	ND	ND	ND	NF	NF	NF	NF	NF	NF
RI-3XD	ND	ND	ND	ND	NF	NF	NF	NF	NF	NF
RI-4S	ND	ND	ND	ND	NF	NF	NF	NF	NF	NF
RI-4D	ND	ND	ND	ND	NF	NF	NF	NF	NF	NF
RI-5S	ND	ND	ND	ND	NF	NF	NF	NF	NF	NF
RI-5S	ND	ND	ND	ND	NF	NF	NF	NF	NF	NF
RI-5D	ND	ND	ND	ND	NF	NF	NF	NF	60	NF
RI-6	ND	ND	ND	ND	NF	NF	NF	NF	NF	NF
RI-7	ND	ND	ND	ND	NF	NF	NF	NF	NF	NF
RI-8	ND	ND	ND	ND	NF	NF	NF	NF	NF	NF
RI-9	23	ND	ND	ND	8	9	NF	NF	1500	NF
RI-10	ND	ND	ND	ND	NF	NF	NF	NF	NF	NF
RI-10XD	ND	ND	(2)	ND	NF	NF	NF	NF	NF	NF
RI-11	ND	ND	ND	ND	NF	NF	NF	NF	NF	NF
RI-11XD	ND	ND	(4)	ND	NF	NF	5	NF	NF	11
RI-12S	ND	ND	ND	ND	NF	NF	NF	NF	NF	NF
RI-12D	ND	ND	ND	ND	NF	NF	NF	NF	NF	NF
RI-13S	ND	ND	ND	ND	NF	NF	NF	NF	NF	NF
RI-13D	ND	ND	ND	ND	NF	NF	NF	NF	NF	NF
RI-14S	ND	ND	ND	ND	NF	NF	NF	NF	NF	NF
RI-14D	ND	ND	ND	ND	NF	NF	NF	NF	NF	5
RI-15S	ND	ND	ND	ND	NF	NF	NF	NF	NF	NF
RI-15D	(3)	(3)	(3)	(3)	NF	NF	NF	(4)	45	NF
RI-16	ND	ND	ND	ND	NF	NF	NF	NF	NF	NF
RI-16	ND	ND	ND	ND	NF	NF	NF	NF	NF	NF
RI-17	ND	ND	ND	ND	NF	NF	NF	NF	43	NF
RI-17	ND	ND	ND	ND	NF	NF	NF	NF	51	NF
RI-18	ND	ND	(3)	ND	NF	NF	NF	NF	NF	NF
RI-19S	ND	ND	ND	ND	NF	NF	NF	NF	NF	NF
RI-19D	ND	ND	ND	ND	NF	NF	NF	NF	NF	NF
RI-20S	ND	ND	ND	ND	NF	NF	NF	NF	NF	NF
RI-20S	ND	ND	ND	ND	NF	NF	NF	NF	NF	NF
RI-20D	ND	ND	ND	ND	NF	NF	7	NF	NF	[illegible]
RI-21S	ND	ND	ND	ND	NF	NF	NF	NF	NF	NF
RI-21D	ND	ND	ND	ND	NF	NF	5	NF	NF	16
RI-21XD	ND	ND	ND	ND	NF	NF	NF	NF	NF	[illegible]
RI-22S	ND	ND	ND	ND	NF	NF	NF	NF	NF	NF
RI-22D	ND	ND	ND	ND	NF	NF	NF	NF	NF	NF
RI-23S	ND	ND	ND	ND	NF	NF	NF	NF	NF	NF
RI-23D	ND	ND	ND	ND	NF	NF	6	NF	NF	[illegible]
RI-24S	ND	ND	ND	ND	NF	NF	NF	NF	NF	NF
RI-24D	ND	ND	ND	ND	NF	NF	NF	NF	NF	NF
RI-24XD	ND	ND	ND	ND	NF	NF	NF	NF	NF	NF
RI-25	ND	ND	ND	ND	NF	NF	NF	NF	NF	[illegible]
RI-25	ND	ND	ND	ND	NF	NF	NF	NF	NF	[illegible]
RI-26	ND	ND	ND	ND	NF	NF	NF	NF	NF	NF
RI-27S	ND	ND	ND	ND	NF	NF	NF	NF	NF	NF
RI-27D	ND	ND	ND	ND	NF	NF	NF	NF	NF	NF
RI-27XD	ND	ND	ND	ND	NF	NF	NF	NF	NF	NF
RI-28S	ND	ND	ND	ND	NF	NF	NF	NF	NF	NF
RI-28D	ND	ND	ND	ND	NF	NF	NF	NF	NF	NF
RI-29S	ND	ND	ND	ND	NF	NF	NF	NF	NF	NF
RI-29D	ND	ND	ND	ND	NF	NF	NF	NF	NF	9
RI-31S	ND	ND	ND	ND	NF	NF	NF	NF	NF	NF
RI-31D	ND	ND	ND	ND	NF	NF	NF	NF	NF	NF
RI-32D	ND	ND	ND	ND	NF	NF	NF	NF	NF	NF
RI-32XD	ND	ND	ND	ND	NF	NF	NF	NF	NF	NF
244-011S	20	ND	(3)	ND	7	NF	17	NF	220	NF
244-0115	ND	ND	ND	ND	NF	NF	NF	NF	NF	NF
244-0131	ND	ND	ND	44	NF	NF	NF	NF	5	NF
244-0124	ND	ND	9	ND	NF	NF	NF	NF	NF	NF
244-0125	ND	ND	(4)	ND	NF	NF	NF	NF	NF	NF
244-0126	ND	ND	(4)	ND	NF	NF	NF	NF	175	NF
244-0129	ND	ND	ND	ND	NF	NF	NF	NF	NF	NF
244-0181	ND	ND	11	ND	NF	NF	NF	NF	NF	NF

NOTES: 1. ND indicates below method detection limits (see JTC reports dated 10/2/85 and 12/12/85 for detection limits).

2. Values reported in parentheses were detected at concentrations that are below the detection limit (see JTC reports dated 10/2/85 and 12/12/85 for detection limits).

3. NF indicates not found. For tentatively identified volatile organic compounds, the reported values are estimated concentrations.

4. All values are reported in ug/l, unless otherwise noted.

TABLE 4-25, continued

SUMMARY OF JTC ANALYTICAL DATA
AUGUST AND OCTOBER 1985

WELL NO.	BASE/NEUTRAL EXTRACTABLES ANILINE	4-CHLORO-ANILINE	2-NITRO ANILINE	4-NITRO ANILINE	1,2-DI CHLORO BENZENE	1,3-DI CHLORO BENZENE	1,4-DI CHLORO BENZENE	1,2,4-TRI CHLORO BENZENE	AZO BENZENE	BENZYL ALCOHOL	NAPTHALENE	BIS (2-CHLOROETHYL) ETHER	N-NITROSO-DIPHENYL AMINE
RI-1S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-1D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-1XD	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-2S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-2D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-2XD	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-3S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-3D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	(2)	ND
RI-3XD	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-4S	(5)	(5)	ND	ND	25	(4)	(2)	17	ND	ND	ND	(7)	ND
RI-4D	22	17	ND	ND	77	10	(5)	59	ND	ND	ND	ND	(2)
RI-5S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-5S	ND	ND	ND	ND	(2)	ND	ND	ND	ND	ND	ND	ND	ND
RI-5D	ND	10	ND	ND	106	(2)	11	51	ND	ND	ND	ND	ND
RI-6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-8	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-9	(8)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-10XD	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	30
RI-11	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-11XD	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-12S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-12D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-13S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-13D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-14S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-14D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-15S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-15D	ND	ND	ND	ND	101	ND	(6)	(6)	ND	ND	ND	ND	ND
RI-16	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-16	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-17	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-17	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-18	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-19S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-19D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-20S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-20S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-20D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-21S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-21D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-21XD	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-22S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-22D	ND	ND	ND	ND	(2)	ND	ND	ND	ND	ND	ND	ND	ND
RI-23S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-23D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-24S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-24D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-24XD	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-25	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-25	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-26	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-27S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-27D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-27XD	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-28S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-28D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-29S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-29D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-31S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-31D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-32D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-32XD	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
744-0115	(3)	ND	ND	ND	ND	ND	ND	ND	ND	ND	(2)	ND	ND
744-0115	(3)	ND	ND	ND	ND	ND	ND	ND	ND	ND	(2)	ND	ND
744-0131	3300	ND	(6)	34	3160	14	122	1760	10	(6)	152	ND	ND
744-0174	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
744-0175	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
744-0176	ND	ND	ND	ND	ND	ND	(3)	ND	ND	ND	ND	ND	ND
744-0179	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
744-0181	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

NOTES:
1. ND indicates below method detection limits (see JTC reports dated 10/2/85 and 12/12/85 for detection limits).
2. Values reported in parentheses were detected at concentrations that are below the detection limit (see JTC reports dated 10/2/85 and 12/12/85 for detection limits).
3. NF indicates not found. For tentatively identified volatile organic compounds, the reported values are estimated concentrations.
4. All values are reported in ug/l, unless otherwise noted.

TABLE 4-25, continued

SUMMARY OF JTC ANALYTICAL DATA
AUGUST AND OCTOBER 1985

	ACID EXTRACTABLES						
WELL NO.	BENZOIC ACID	2-CHLORO PHENOL	2-METHYL PHENOL	4-METHYL PHENOL	PENTA CHLORO PHENOL	PHENOL	2,4,5-TRI CHLORO PHENOL
RI-1S	ND	ND	ND	ND	ND	ND	ND
RI-1D	ND	ND	ND	ND	ND	ND	ND
RI-1XD	ND	ND	ND	ND	ND	ND	ND
RI-2S	ND	ND	ND	ND	ND	ND	ND
RI-2D	ND	ND	ND	ND	ND	ND	ND
RI-2XD	ND	ND	ND	ND	ND	ND	ND
RI-3S	ND	ND	ND	ND	ND	ND	ND
RI-3D	ND	ND	ND	ND	ND	ND	ND
RI-3XD	ND	ND	ND	ND	ND	ND	ND
RI-4S	ND	ND	ND	ND	ND	ND	ND
RI-4D	ND	ND	ND	ND	ND	ND	ND
RI-5S	ND	ND	ND	ND	ND	ND	ND
RI-5S	ND	ND	ND	ND	ND	ND	ND
RI-5D	ND	ND	ND	ND	ND	ND	ND
RI-6	ND	ND	ND	ND	ND	ND	ND
RI-7	ND	ND	ND	ND	ND	ND	ND
RI-8	ND	ND	ND	ND	ND	ND	ND
RI-9	ND	ND	ND	ND	ND	ND	ND
RI-10	ND	ND	ND	ND	ND	ND	ND
RI-10XD	ND	ND	ND	ND	ND	ND	ND
RI-11	ND	ND	ND	ND	ND	ND	ND
RI-11XD	ND	ND	ND	ND	ND	20	ND
RI-12S	ND	ND	ND	ND	ND	ND	ND
RI-12D	ND	ND	ND	ND	ND	ND	ND
RI-13S	ND	ND	ND	ND	ND	ND	ND
RI-13D	ND	ND	ND	ND	ND	ND	ND
RI-14S	ND	ND	ND	ND	ND	ND	ND
RI-14D	ND	ND	ND	ND	ND	ND	ND
RI-15S	ND	ND	ND	ND	ND	ND	ND
RI-15D	ND	ND	ND	ND	ND	ND	ND
RI-16	ND	ND	ND	ND	ND	ND	ND
RI-16	ND	ND	ND	ND	ND	ND	ND
RI-17	ND	ND	ND	ND	ND	ND	ND
RI-17	ND	ND	ND	ND	ND	ND	ND
RI-18	ND	ND	ND	ND	ND	ND	ND
RI-19S	ND	ND	ND	ND	ND	ND	ND
RI-19D	ND	ND	ND	ND	ND	ND	ND
RI-20S	ND	ND	ND	ND	ND	ND	ND
RI-20S	ND	ND	ND	ND	ND	ND	ND
RI-20D	ND	ND	ND	ND	ND	ND	ND
RI-21S	ND	ND	ND	ND	ND	ND	ND
RI-21D	ND	ND	ND	ND	ND	ND	ND
RI-21XD	ND	ND	ND	ND	ND	ND	ND
RI-22S	ND	ND	ND	ND	ND	ND	ND
RI-22D	ND	ND	ND	ND	ND	ND	ND
RI-23S	ND	ND	ND	ND	ND	ND	ND
RI-23D	ND	ND	ND	ND	ND	ND	ND
RI-24S	ND	ND	ND	ND	ND	ND	ND
RI-24D	ND	ND	ND	ND	ND	ND	ND
RI-24XD	ND	ND	ND	ND	ND	ND	ND
RI-25	ND	ND	ND	ND	ND	ND	ND
RI-25	ND	ND	ND	ND	ND	ND	ND
RI-26	ND	ND	ND	ND	ND	ND	ND
RI-27S	ND	ND	ND	ND	ND	ND	ND
RI-27D	ND	ND	ND	ND	ND	ND	ND
RI-27XD	ND	ND	ND	ND	ND	ND	ND
RI-28S	ND	ND	ND	ND	ND	ND	ND
RI-28D	ND	ND	ND	ND	ND	ND	ND
RI-29S	ND	ND	ND	ND	ND	ND	ND
RI-29D	ND	ND	ND	ND	ND	ND	ND
RI-31S	ND	ND	ND	ND	ND	ND	ND
RI-31D	ND	ND	ND	ND	ND	ND	ND
RI-32D	ND	ND	ND	ND	ND	ND	ND
RI-32XD	ND	ND	ND	ND	ND	ND	ND
744-0115	ND	ND	ND	ND	ND	ND	ND
744-0115	ND	ND	ND	ND	ND	ND	ND
744-0131	204	36	632	36	12	496	(8)
744-0174	ND	ND	ND	ND	ND	ND	ND
744-0175	ND	ND	ND	ND	ND	ND	ND
744-0176	ND	ND	ND	ND	ND	ND	ND
744-0179	ND	ND	ND	ND	ND	ND	ND
744-0181	ND	ND	ND	ND	ND	ND	ND

NOTES: 1. ND indicates below method detection limits (see JTC reports dated 10/2/85 and 12/12/85 for detection limits).

2. Values reported in parentheses were detected at concentrations that are below the detection limit (see JTC reports dated 10/2/85 and 12/12/85 for detection limits).

3. NF indicates not found. For tentatively identified volatile organic compounds, the reported values are estimated concentrations.

4. All values are reported in ug/l, unless otherwise noted.

TABLE 4-25, cont'd

SUMMARY OF JTC ANALYTICAL DATA
JUNE 1986

WELL NO.	BENZENE	BROMOFORM	CHLORO BENZENE	TRI CHLORO ETHENE	1,2-DI CHLORO ETHANE	CHLORO FORM	TRANS-1,2 DICHLORO ETHENE	TETRA CHLORO ETHENE	TOLUENE	METHYLENE CHLORIDE	1,1-DI CHLORO ETHANE	1,1,2,2 TETRA CHLOROETHANE	1,1,1-TRI CHLORO ETHANE	1,1,2-TRI CHLORO ETHANE	ACETONE	1,2-DI CHLORO PROPANE	VINYL CHLORIDE	CARBON DISULFIDE	XYLENES
	VOLATILE ORGANIC COMPOUNDS																		
RI-11D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	25	ND
RI-3S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	9	ND
RI-3S 1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	9	ND
RI-3D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	6	ND
RI-5D	9	ND	415	63	(2)	48	63	110	ND	ND	ND	ND	ND	ND	ND	ND	ND	(4)	ND
RI-6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-8	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	26	ND
RI-9	55	ND	1600	5000	(2)	ND	524	ND	(3)	ND	(2)	58	ND	7	ND	22	ND	ND	ND
RI-10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	18	ND
RI-11	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-13S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	5	ND
RI-13D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	6	ND
RI-14S	ND	ND	ND	ND	ND	(2)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	18	ND
RI-14D	(2)	ND	ND	ND	ND	(4)	ND	(2)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-15S	ND	ND	ND	ND	ND	(2)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-15D	(2)	ND	23	(2)	ND	(2)	(4)	(2)	ND	2800	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-16	(2)	ND	9	9	ND	ND	ND	(4)	ND	ND	ND	ND	ND	ND	1100	ND	ND	11	ND
RI-17	38	ND	180	1000	ND	ND	46	ND	ND	ND	ND	27	ND	ND	150	(4)	ND	12	ND
RI-19S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	54	ND	ND	ND	ND
RI-19D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-20S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	170	ND	ND	ND	ND
RI-20D	ND	ND	ND	ND	ND	(2)	ND	ND	ND	ND	ND	ND	ND	ND	210	ND	ND	ND	ND
RI-21S	ND	ND	ND	ND	ND	(3)	ND	ND	ND	4000	ND	ND	ND	ND	100	ND	ND	ND	ND
RI-22S	7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	950	ND	ND	ND	ND
RI-22D	ND	ND	ND	15	ND	ND	7	60	ND	ND	ND	ND	ND	ND	110	ND	ND	ND	ND
RI-23D	(1)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1300	ND	ND	ND	ND
RI-31S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-31D	ND	ND	ND	6	ND	(3)	10	ND	ND	ND	ND	ND	ND	ND	2250	ND	ND	ND	ND
744-0159	14	ND	13	5	ND	(3)	ND	10	ND	ND	ND	ND	ND	ND	1700	ND	ND	20	ND
744-0160	ND	ND	5	(4)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	560	ND	ND	ND	ND
744-0161	96	ND	554	134	ND	ND	155	90	ND	ND	ND	ND	ND	(3)	3000	(4)	ND	18	ND
Fld Blk	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Trp Blk	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Decon 1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	14000	ND	ND	ND	ND
Decon 2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1400	ND	ND	ND	ND

NOTES: ND indicates below method detection limit (See JTC Report dated 9/23/86 for detection limits).

1 indicates duplicate sample.

Results are reported in ug/l.

TABLE 4-25, cont'd

SUMMARY OF JTC ANALYTICAL DATA
JUNE 1986

WELL NO.	ANILINE	4-CHLORO-ANILINE	2-NITRO ANILINE	4-NITRO ANILINE	1,2-DI CHLORO BENZENE	1,3-DI CHLORO BENZENE	1,4-DI CHLORO BENZENE	1,2,4-TRI CHLORO BENZENE	AZO BENZENE	BENZYL ALCOHOL	NAPTHALENE	BIS (2-CHLOROETHYL) ETHER	N-NITROSO-DIPHENYL AMINE	BENZOIC ACID	2-CHLORO PHENOL	2-METHYL PHENOL	4-METHYL PHENOL	PENTA CHLORO PHENOL	PHENOL	2,4,5-TRI CHLORO PHENOL
	BASE/NEUTRAL EXTRACTABLES													ACID EXTRACTABLES						
RI-1D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-3S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-3S 1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-3D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	(2)	ND	ND	ND	ND	ND	ND	ND	ND
RI-5D	ND	10	ND	ND	165	(3)	13	42	ND	ND	11	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-8	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-9	16	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-11	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-13S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-13D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-14S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-14D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-15S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-15D	ND	ND	ND	ND	(4)	ND	ND	(4)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-16	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-17	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-19S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-19D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-20S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-20D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-21S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-22S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-22D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-23D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-31S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RI-31D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
744-0159	ND	ND	ND	ND	(5)	ND	ND	(3)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
744-0160	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
744-0161	(8)	ND	ND	ND	256	(3)	12	268	ND	ND	ND	ND	ND	ND	(3)	ND	ND	ND	ND	ND
Fld Blk	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Trp Blk	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Decon 1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Decon 2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

NOTES: ND NOTES: ND indicates below method detection limit (See JTC Report dated 9/23/86 for detection limits).

1 1 indicates duplicate sample.

R Results are reported in ug/l.

CIB 004 1984

Compound	Mean (ppb)	Standard Deviation (ppb)	Maximum (ppb)	Minimum (ppb)
Benzene	346	778	2400	<10
Chlorobenzene	3133	3162	8400	<10
Chloroform	218	453	1400	<10
Ethyl Benzene	221	559	1700	<10
Trichloroethene	4168	7896	25000	<10
Tetrachloroethene	2866	3956	12000	<10
1,1,1-Trichloroethane	16	6	60	<10
1,2-Dichloroethane	12	4	22	<10
Trans-1,2-Dichloroethene	153	236	750	<10
Toluene	2293	4513	14000	<10

The volatile organics listed above are representative of the plume of groundwater contaminaton detected within the Primary and Lower Cohansey water-bearing zones. The summary statistics are derived from six selected monitoring wells that have consistently exhibited the highest concentrations of organic contamination. Data from the following monitoring wells was used: 744-0111, 744-0115, 744-0131, 744-0132, 744-0133, and 744-0134. In addition, data from two mini-piezometers, TP-4A and TP-4D, was utilized.

The volatile organic compounds listed below have been detected in at least one well at the stated maximum concentration, but are apparently not widespread. The data are not sufficient to allow calculation of descriptive statistics. Figures in parenthesis indicate levels were below method detection limits.

Compound	Maximum Concentration (ppb)
Bromoform	(2)
1,1-Dichloroethane	21
1,1,2,2-Tetrachloroethane	10
1,2-Dichloropropane	23
Methylene Chloride	130
Vinyl Chloride	(3)
Carbon Disulfide	9
Xylenes	44

The following non-priority pollutant volatiles were also tentatively identified:

Compound	Maximum Concentration (ppb)
Chloropropene	8
Methyl Propanol	9
Pentanol	17
Tetrahydrofuran	(4)
Trichloropropane	1500
Trimethylpentene	11

Base/Neutral Extractable Constituents

The base/neutral extractable organics that are detected in significant concentrations and appear to be relatively widespread are listed below. The summary statistics were derived from the data points described above.

Compound	Mean (ppb)	Standard Deviation (ppb)	Maximum (ppb)	Minimum (ppb)
1,2-Dichlorobenzene	2449	3180	10000	<10
Nitrobenzene	8111	12668	39000	<10
Naphthalene	132	197	630	<10

The base/neutral extractable organic compounds listed below have been detected in at least one well at the stated maximum concentration, but are apparently not widespread. The data are not sufficient to allow calculation of descriptive statistics.

Compound	Maximum Concentration (ppb)
Aniline	3300
4-Chloroaniline	17
2-Nitroaniline	(6)
4-Nitroaniline	34
Azo Benzene	10
Benzo-a-anthracene	30
Benzyl Alcohol	(6)
Bis-(2-chloroethoxy)-methane	240
Bis-(2-chloroethyl)-ether	(7)
1,3-Dichlorobenzene	14
1,4-Dichlorobenzene	122
Di-N-Butyl Phthalate	140
Di-Ethyl Phthalate	10
Hexachlorobenzene	15
Hexachlorobutadiene	25
Isophorone	10
Monochlorobenzene	70
Ortho-chloro-toluene	10
1,2,4-Trichlorobenzene	1760

Acid Extractable Constituents

The acid extractable organics typically do not constitute a significant portion of the contaminant load in the groundwater system. To date only a single monitoring well, 744-0131, had been found to contain a significant suite of acid extractable organic compounds. The data from this well are summarized below.

Compound	Maximum Concentration (ppb)
Benzoic Acid	204
2-Chlorophenol	36
2-Methylphenol	632
4-Methylphenol	36
Pentachlorophenol	12
Phenol	496
2,4,5-Trichlorophenol	(8)

Contaminant Velocity Estimates

It has long been recognized that significant differences in the rates of migration exist between different chemical species in the groundwater environment. Conservative, or non-reactive constituents are defined as those which migrate essentially at the prevailing groundwater velocity and thus without significant attenuation. Chloride, for example, has long been recognized as a classic, conservative compound and represents an excellent indicator of the leading edge of a contaminant plume.

Reactive constituents, on the other hand, participate in physical, chemical or biochemical reactions that have the net effect of attenuating their migration in groundwater. Attenuation mechanisms include sorption, oxidation reduction, hydrolysis, and biodegradation. Of these mechanisms, sorption is among the most important and best understood. The adsorption coefficient referenced to soil organic content, K_{oc}, has been empirically correlated to several other properties of various chemicals, in particular, to water solubility and to the octanol/water partition coefficient (K_{ow}). Several of these correlations are presented on Table 4-26. Care must be exercised in selecting which equation is most appropriate for a given compound. One should typically select the equation that included the compound of interest or a close relative thereof in the derivation of the equation.

Ultimately, the intent is to determine the relative retardation that a compound will experience with respect to the rate of groundwater flow. These "retardation factors" (R) can be used, for example, to estimate aquifer flushing times or to assess the likely time of contaminant appearance or breakthrough. It can be shown that:

$$R = 1 + (p/n) K_d$$

Where: p = bulk solids density
n = porosity
K_d = soil/water distribution coefficient

With this definition:

$$V_c = \frac{V_w}{R}$$

where: V_c = velocity of contaminant migration (l/t)
V_w = velocity of groundwater flow (l/t)

TABLE 4-26

ADSORPTION COEFFICIENTS AND EMPIRICAL CORRELATIONS

Kenaga and Goring, 1978

$$\log K_{oc} = [0.55\ (S)] + 3.64$$

$$r^2 = 0.71$$

Where: S = Solubility, in mg/l

(106 chemicals used, wide variety)

$$\log K_{oc} = [0.544\ \log K_{ow}] + 1.377$$

$$r^2 = 0.74$$

(45 chemicals used, wide variety)

Karickhoff, et al., 1979

$$\log K_{oc} = [-0.54\ (S)] + 0.44$$

$$r^2 = 0.94$$

Where: S = Solubility, in mole fraction

(10 chemicals used, mostly aromatic or polynuclear aromatic compounds)

$$\log K_{oc} = [1.00\ (\log K_{ow})] - 0.21$$

$$K_{oc} = 0.63\ (K_{ow})$$

$$r^2 = 1.00$$

(10 chemicals used, mostly aromatic or polynuclear aromatic compounds)

Chiou, et al., 1979

$$\log K_{oc} = [0.557\ (\log S)] + 4.277$$

$$r^2 = 0.99$$

Where: S = Solubility, in umoles/l

(15 chemicals used, chlorinated hydrocarbons)

K_{oc} = soil adsorption coefficient referenced to organic content

K_{ow} = octanol/water partition coefficient

r2 = regression coefficient

Consequently, to compute R, we need values for p, n, and K_d. The ratio p/n is typically in the range of four (4) to ten (10) for natural soils. K_d can be calculated using the relationship developed by Karickhoff and others (1978). Karickhoff and his co-workers evaluated the adsorption of hydrophobic organics to river and lake sediments and noted that:

Only the fine-grained particle sizes participated in adsorption;

The percentage of organic matter was controlling; and

$K_{oc} = 0.63\ K_{ow}$, where K_{ow} is the octanol/water partition coefficient.

Since: $K_d = f_{oc} K_{oc}$

and: $K_{oc} = 0.63\ K_{ow}$

then: $K_d = 0.63\ f_{oc} K_{ow}$

where: f_{oc} = is the fractional organic content

Thirty-two soil samples were submitted to Galbraith Laboratories of Knoxville, Tennessee, for determination of fractional organic content. Fourteen of the soil samples were representative of the Kirkwood Formation; eighteen samples of the Cohansey Formation were tested. Within the eighteen Cohansey Formation samples, nine were samples of the upper, primary, and lower sand units, while the remaining nine samples were from the organic sand member. The results of the testing program are summarized on Table 4-27.

The average fractional organic content of the Cohansey Formation is approximately 0.13%.

Calculated retardation factors for selected volatile and base/neutral extractable organic compounds are presented on Table 4-28. The retardation factors were calculated using the correlation developed by Chiou and others (1979) and incorporates the assumption that soil organic contents are sufficiently high to control adsorption. This particular correlation was developed using several chlorinated organic compounds and is an empirical relationship between water solubility and the soil distribution coefficient referenced to soil organic content. The calculations are based, as well, upon an assumption that the ratio of bulk solids density to pore volume (p/n) is equal to six (6). The actual calculations are presented in Volume IV.

Table 4-29 integrates the calculated retardation factors with the expected range of groundwater velocity to derive estimates of contaminant velocity for the selected organic constituents. Although precise field verification of these estimates is not feasible at the Toms River site, the existing data is sufficient to allow a rough evaluation of relative plume advancement. For example, using an hydraulic conductivity of 5.0×10^{-2} cm/sec for the Cohansey Sand, the estimated contaminant velocity of trichloroethene (264 ft/yr) is approximately two and one half times faster than that of 1,2-Dichlorobenzene (106 ft/yr). Assuming both contaminants were introduced into the groundwater

TABLE 4-27

SUMMARY OF SOIL ORGANIC CONTENT DATA

Boring Number	Sample Number	Sample Depth	Lithologic Unit	f_{oc}%
RI-14	2	39–41	BLACK ORGANIC SAND	1.22
RI-14	3	41–43	BLACK ORGANIC SAND	5.02
RI-23	1	75–77	BLACK ORGANIC SAND	0.57
RI-24XD	1	89–91	BLACK ORGANIC SAND	0.54
RI-27	1	38–40	BLACK ORGANIC SAND	0.06
RI-16	2	42–44	BLACK ORGANIC SAND	2.57
RI-16	1	42–44	BLACK ORGANIC SAND	2.39
RI-24	1	66–63	BLACK ORGANIC SAND	0.94
RI-19	3	32–34	BLACK ORGANIC SAND	0.10
RI-179	9	16–18	UPPER COHANSEY	0.06
RI-180	3	4–6	UPPER COHANSEY	0.50
RI-179	6	10–12	PRIMARY COHANSEY	0.06
RI-180	15	28–30	PRIMARY COHANSEY	0.06
RI-15	9	69–71	PRIMARY COHANSEY	0.09
RI-180	12	22–24	PRIMARY COHANSEY	0.06
RI-14	4	54–56	PRIMARY COHANSEY	0.09
RI-180	31	64–66	LOWER COHANSEY	0.11
RI-24XD	3	93–95	KIRKWOOD	0.48
RI-24XD	15	100–102	KIRKWOOD	0.73
RI-24XD	18	155–157	KIRKWOOD	0.20
RI-24XD	26	195–197	KIRKWOOD	1.48
RI-16	9	71–73	KIRKWOOD	0.39
RI-16	10	73–75	KIRKWOOD	0.90
RI-20	11	94–96	KIRKWOOD	1.21
RI-180	52	78–80	KIRKWOOD	1.26
RI-180	47	125–126.5	KIRKWOOD	0.91
RI-179	48	103–105	KIRKWOOD	0.09
RI-180	38	78–80	KIRKWOOD	0.41
RI-14	7	60–62	KIRKWOOD	2.43
RI-14	8	62–64	KIRKWOOD	0.64
RI-15	11	73–75	KIRKWOOD	0.38
RI-21	11	97–99	KIRKWOOD	1.31

Mean f_{oc} % for Kirkwood = 0.85 %
Standard deviation f_{oc} = 0.59 %

Mean f_{oc} % Black Organic Sand = 1.49 %
Standard deviation f_{oc} = 1.51 %

Mean f_{oc} % for Cohansey = 0.13 %
Standard deviation f_{oc} = 0.14 %

TABLE 4-28

ESTIMATED RETARDATION FACTORS

Cohansey Formation

Chemical	Solubility (in umoles/l)	K_{oc}	K_d	R
Benzene	22800	70.7	0.09	1.55
Chlorobenzene	4420	176	0.23	2.36
Chloroform	67200	38.7	0.05	1.30
1,2-Dichlorobenzene	680	500	0.64	4.86
1,3-Dichlorobenzene	469	615	0.79	5.75
1,4-Dichlorobenzene	333	745	0.96	6.76
1,2-Trans Dichloroethene	6180	146	0.19	2.13
Ethylbenzene	1430	331	0.43	3.56
Tetrachloroethene	904	427	0.55	4.30
Toluene	5590	155	0.20	2.20
Trichloroethene	8330	124	0.16	1.96

RETARDATION FACTORS BASED UPON AVERAGE ORGANIC CONTENT = 0.13%

flow system at roughly the same time, it would be expected that trichloroethene would have advanced further than 1,2,dichlorobenzene. This scenario is confirmed by a review of these two plumes on Figures 4-48 and 4-51, respectively.

Distribution of Contamination

In this section, the distribution of contamination within each of the major water-bearing zones will be described. The discussions are based primarily upon the previously described database developed during the course of this investigation.

Kirkwood No. 2 Sand Water-Bearing Zone

There is no indication of groundwater contamination within the Kirkwood No. 2 Sand water-bearing zone. Nine monitoring wells are screened within this zone; six are located within the plant site, while three are located off-site near the Toms River. Two of the monitoring wells indicated a trace of volatile organics. Carbon disulfide was reported at a concentration of 11 ppb in monitoring well 744-0181; trimethylpentene was tentatively identified at an estimated concentration of 6 ppb in the sample from well RI-21XD. Neither of these compounds can be considered diagnostic of contamination originating at the Toms River Plant. In fact, both compounds are conspicuously absent from the contaminant plume observed in the Cohansey. Accordingly, it is concluded that contamination from the Toms River Plant is not present within the Kirkwood No. 2 Sand water- bearing zone.

Kirkwood No. 1 Sand Water-Bearing Zone

At this time, groundwater monitoring within the Kirkwood No. 1 Sand water-bearing zone is limited to the vicinity of the Equalization Basins. This area was chosen for immediate monitoring because of the potential for downward movement of contaminants in response to hydraulic gradients between the Primary Cohansey water-bearing zone and the Kirkwood No. 1 Sand. Three monitoring wells (744-1108, 744-1109, and 744-1110) are screened within the No. 1 Sand. The results of analyses performed by SR Analytical indicated no detectable Priority Pollutant organics (Table 4-23). Given that the area around the Equalization Basins would most likely represent a worst-case scenario for potential contamination in the Kirkwood No. 1 Sand, the absence of contamination in these wells is encouraging. However, further investigation of the No. 1 Sand is underway and will be focused primarily in areas where both the vertical gradient through the Upper Kirkwood aquitard is downward and the overlying Lower Cohansey is contaminated.

Lower Cohansey Water-Bearing Zone

Groundwater contamination has been detected within the Lower Cohansey water-bearing zone. The contaminant plume consists primarily of a relatively broad suite of volatile and base/neutral extractable organic compounds. There are currently eleven (11) monitoring wells screened within this zone. The compounds detected, their maximum concentrations, and the number of wells in which a particular contaminant was detected are listed on Table 4-30.

TABLE 4-30

SUMMARY OF CONTAMINATION IN THE LOWER COHANSEY

Compound	Maximum Concentration (ppb)	Number of Wells
Volatiles		
Benzene	320	6
Chlorobenzene	820	4
Chloroform	10	2
Methylene Chloride	130	1
Tetrachloroethene	380	4
Toluene	140	3
Trichloroethene	25000	4
Trans-1,2-Dichloro-Ethene	600	4
1,1,2,2-Tetrachloro-Ethane	10	4
Base/Neutral Extractables		
Benzo-a-anthracene	30	1
Di-N-Butyl Phthalate	105	4
Di-Ethyl Phthalate	10	1
1,2 Dichlorobenzene	40	2
Hexachlorobenzene	10	1
Hexachlorobutadiene	20	1
Monochlorobenzene	70	1
Naphthalene	20	1
Nitrobenzene	2700	3
Pyrene	85	3

The generalized configuration of the contaminant plume present within the Lower Cohansey water-bearing zone is depicted on Figure 4-46. This figure is a generalized isoconcentration map of total volatile priority pollutants, and shows the approximate extent of contamination in the Lower Cohansey. While this number of monitoring wells is sufficient to describe the general patterns of contaminant distribution, these patterns should be interpreted with considerable caution. It should be noted, as well, that this map does not represent the distribution of contamination at a single point in time, since data from several separate sampling episodes were used in its preparation. In addition to the actual groundwater quality data from the available monitoring wells, we have made use of data gathered during the drilling of monitoring wells 744-0179, 744-1108, and 744-1109 in the interpretation of the approximate limits of contamination. The additional data consists of soil trace gas analyses of split-spoon samples from the Lower Cohansey obtained during drilling. In the case of the monitoring wells listed above, no anomalous concentrations of trace gases were detected in the relevant soil samples taken from the Lower Cohansey Sand.

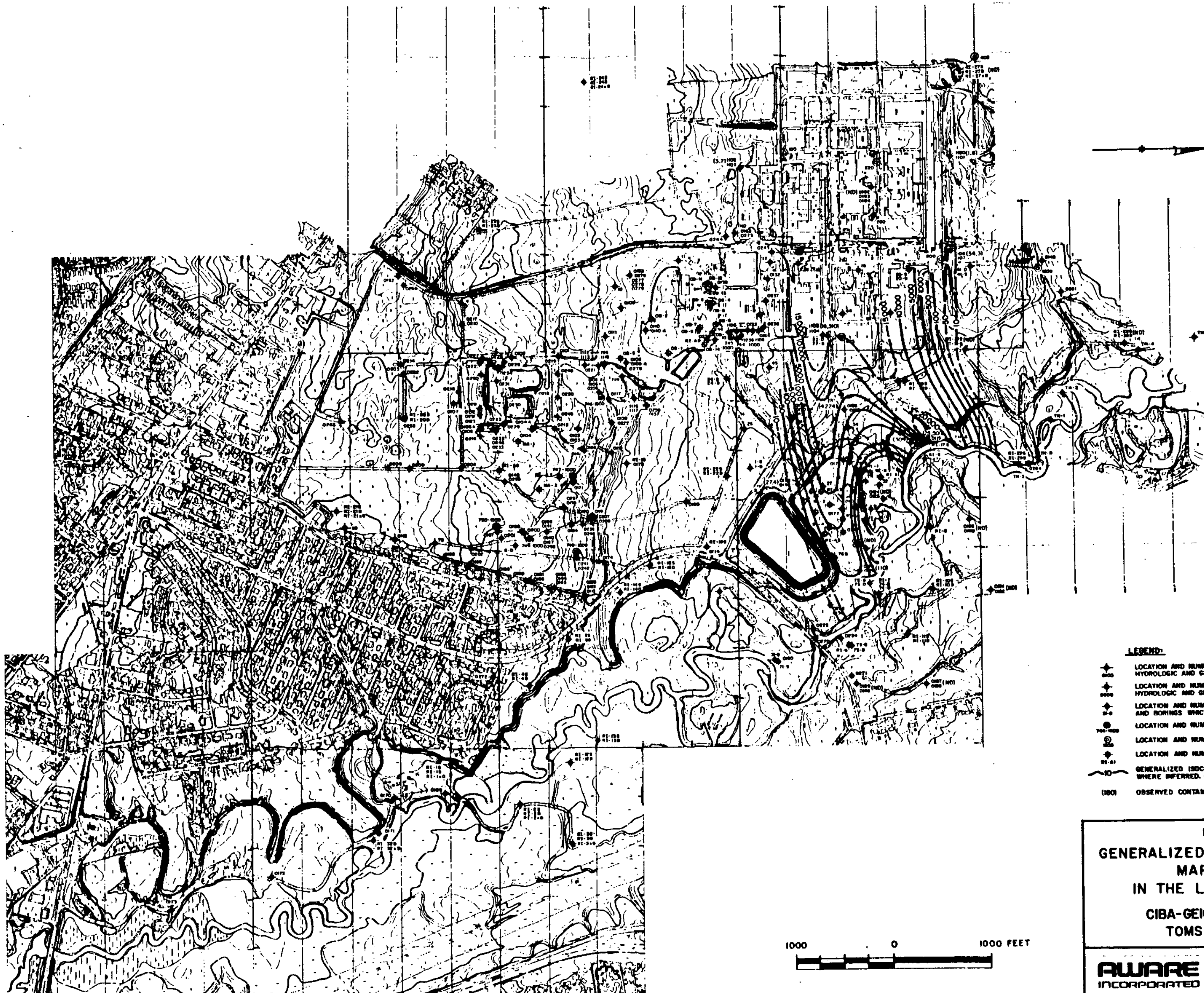
Recognizing the limitations inherent in the preparation of such maps, several observations are worth noting. For example, the apparent source of the contaminant plume in the Lower Cohansey appears to be located within the process or manufacturing area of the plant site. We base this tentative conclusion upon the absence of soil trace gas anomalies in the monitoring wells listed above and upon the pattern of isoconcentration contours depicted on Figure 4-45.

The plume contained within the Lower Cohansey discharges directly to the Toms River near the cooling water intake station and in part, beyond the active channel of the river in the vicinity of RI-9. In addition, migration in an easterly direction towards the Toms River in the vicinity of monitoring well 744-0128 is also suggested.

The occurrence of trichloroethene in the Lower Cohansey at a concentration of 25,000 ppb is particularly noteworthy. This concentration was observed at monitoring well 744-0115 and has subsequently been confirmed by duplicate analysis. This well is screened at the base of the Lower Cohansey at an elevation of approximately 40 feet below mean sea level. The presence of such elevated concentrations resting at the base of the water-bearing zone suggests the possibility of dense, non-aqueous phase liquid contamination.

Primary Cohansey Water-Bearing Zone

A broad plume of groundwater contamination in the Primary Cohansey Sand, and locally in the Upper Cohansey Sand, has been found extending eastward from a north-south trending line of source areas to the Toms River. The plume encompasses an area of approximately 375 acres. Contamination levels vary considerably within the body of the plume, with several major axes of contamination discernable. Beginning in the south, the first major axis stretches from the Former Landfill eastward beneath the northern end of Cardinal Drive to the Toms River. Another axis of contamination stretches eastward from the northern end of the Former Landfill and the Treatment Plant Area. A third axis of contamination extends eastward from the area of the present Equalization Basins towards the Toms River. A subordinate axis trends east-northeastwardly from the southern half of the Process Area to the Toms River in the vicinity of Well RI-9.



LEGEND:

- LOCATION AND NUMBER OF MONITORING WELLS WHICH PROVIDE HYDROLOGIC AND GEOLOGIC INFORMATION
- LOCATION AND NUMBER OF PIEZOMETERS WHICH PROVIDE HYDROLOGIC AND GEOLOGIC INFORMATION
- LOCATION AND NUMBER OF MONITORING WELLS, PIEZOMETERS, AND BORINGS WHICH PROVIDE ONLY GEOLOGIC INFORMATION
- LOCATION AND NUMBER OF PURGE WELLS
- LOCATION AND NUMBER OF PRODUCTION WELLS
- LOCATION AND NUMBER OF AUGER BORINGS
- GENERALIZED ISOCONCENTRATION CONTOUR, IN PPB. DASHED WHERE INFERRED. CONTOUR INTERVAL IS VARIABLE
- (180) OBSERVED CONTAMINANT CONCENTRATION IN PPB

FIGURE 4-46

GENERALIZED ISOCONCENTRATION MAP OF TVPP IN THE LOWER COHANSEY

CIBA-GEIGY CORPORATION TOMS RIVER PLANT

AWARE INCORPORATED
WEST MILFORD, NEW JERSEY
NASHVILLE, TENNESSEE

The contaminant plume within the Primary Cohansey consists primarily of a relatively broad suite of volatile and base/neutral extractable organic compounds, and is marked by elevated chlorides, sulfates, total dissolved solids, and specific conductance.

Except in very close proximity to the potential source areas, contamination is usually concentrated at or near the base of the Primary Cohansey water-bearing zone. This relationship was noted in virtually all of the supplemental test borings performed by AWARE and is reflected in the selected screen intervals for the monitoring wells. The presence of a zone of relatively clear groundwater above the zone of primary contamination has been noted in the literature and has been attributed to the occurrence of recharge from above as well as to density differentials. In most cases, then, contamination in the Primary Cohansey is concentrated near the interface with the underlying Cohansey/Kirkwood Transitional unit and migrates in the direction of prevailing groundwater flow.

The generalized configuration of the contaminant plume present within the Primary Cohansey water-bearing zone is depicted on Figure 4-47. This figure is a generalized isoconcentration map of total volatile priority pollutants, and shows the approximate extent of contamination in the Primary Cohansey. It should be noted that this map does not represent the distribution of contamination at a single point in time, since data from several sampling episodes were used in its preparation. Figures 4-48 through 4-51 are isoconcentration maps for the individual organic compounds trichloroethene, chlorobenzene, tetrachloroethene, and 1,2-dichlorobenzene. Figure 4-45 is an isoconcentration map for chloride.

Recognizing the limitations inherent in the preparation of such maps, several observations are worth noting. Of particular significance is the fact that portions of the plume have reached the Toms River, their ultimate point of discharge, and that no further migration is anticipated. Accordingly, the Toms River and associated flood plain serve as an effective hydrogeologic boundary to groundwater flow and thus to contaminant migration. The evidence for this scenario has been summarized below. The implications for remedial action are discussed in Section 6.0.

In accordance with the basic principles governing groundwater flow, groundwater within the Primary Cohansey flows from areas of higher water table elevation to areas of lower elevation. Inasmuch as Toms River represents the lowest water table elevation in the vicinity of the site, groundwater in the Primary Cohansey flows towards and discharges into the river channel. This discharge condition is illustrated on Figure 4-42 and consists of equal components from the east as well as the west meeting at the river channel.

As shown on Figures 4-47 through 4-51, groundwater contamination in the Primary Cohansey extends from the potential source areas east to the Toms River. The results of chemical analysis from numerous monitoring wells east of the River have, with the exception of a localized area in the vicinity of RI-9, demonstrated no groundwater contaminant migration beyond this boundary.

The hydrodynamics of groundwater flow in the vicinity of monitoring well RI-9 (as discussed in detail on page 4-58) also support the scenario of the Toms

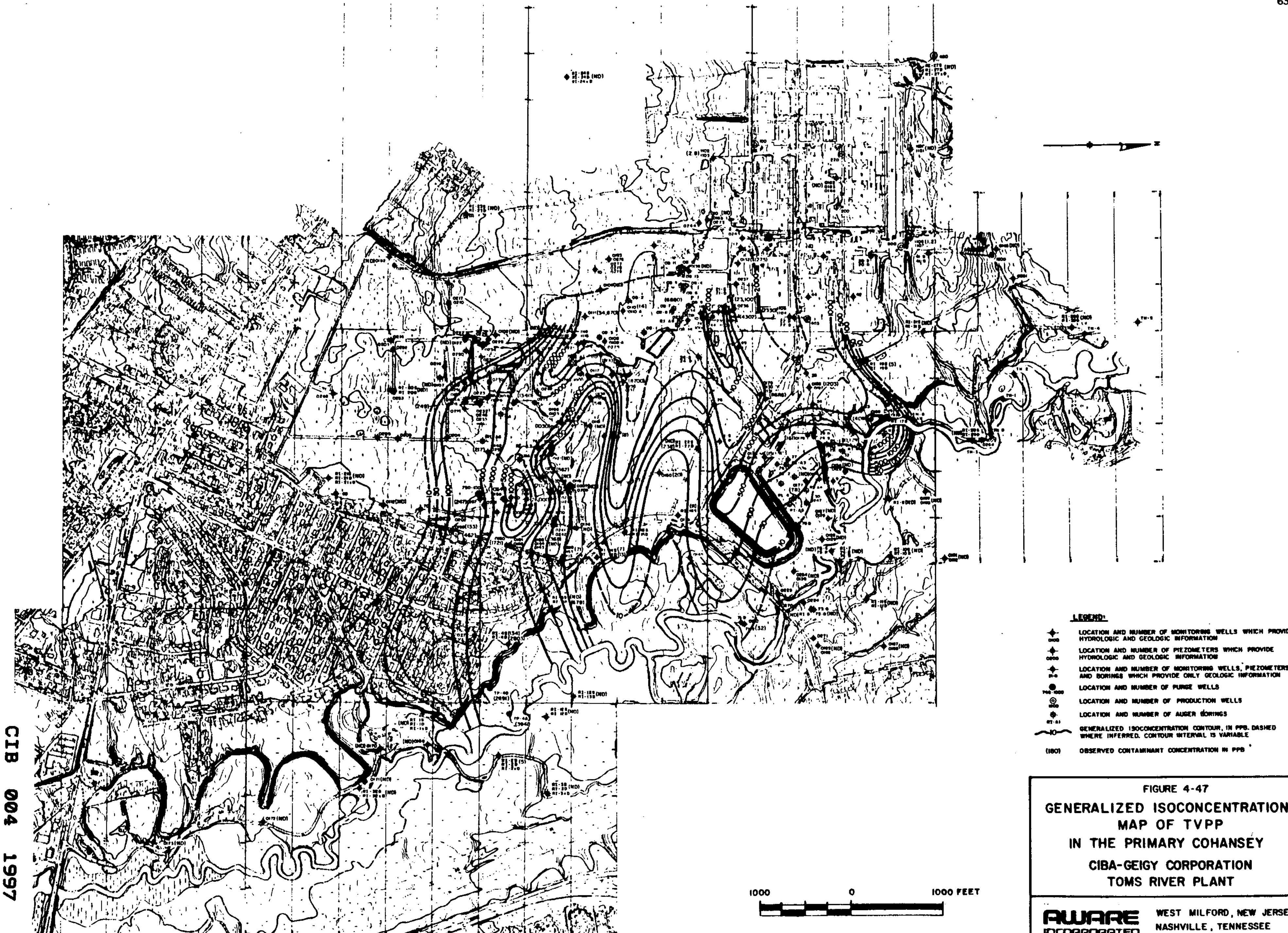
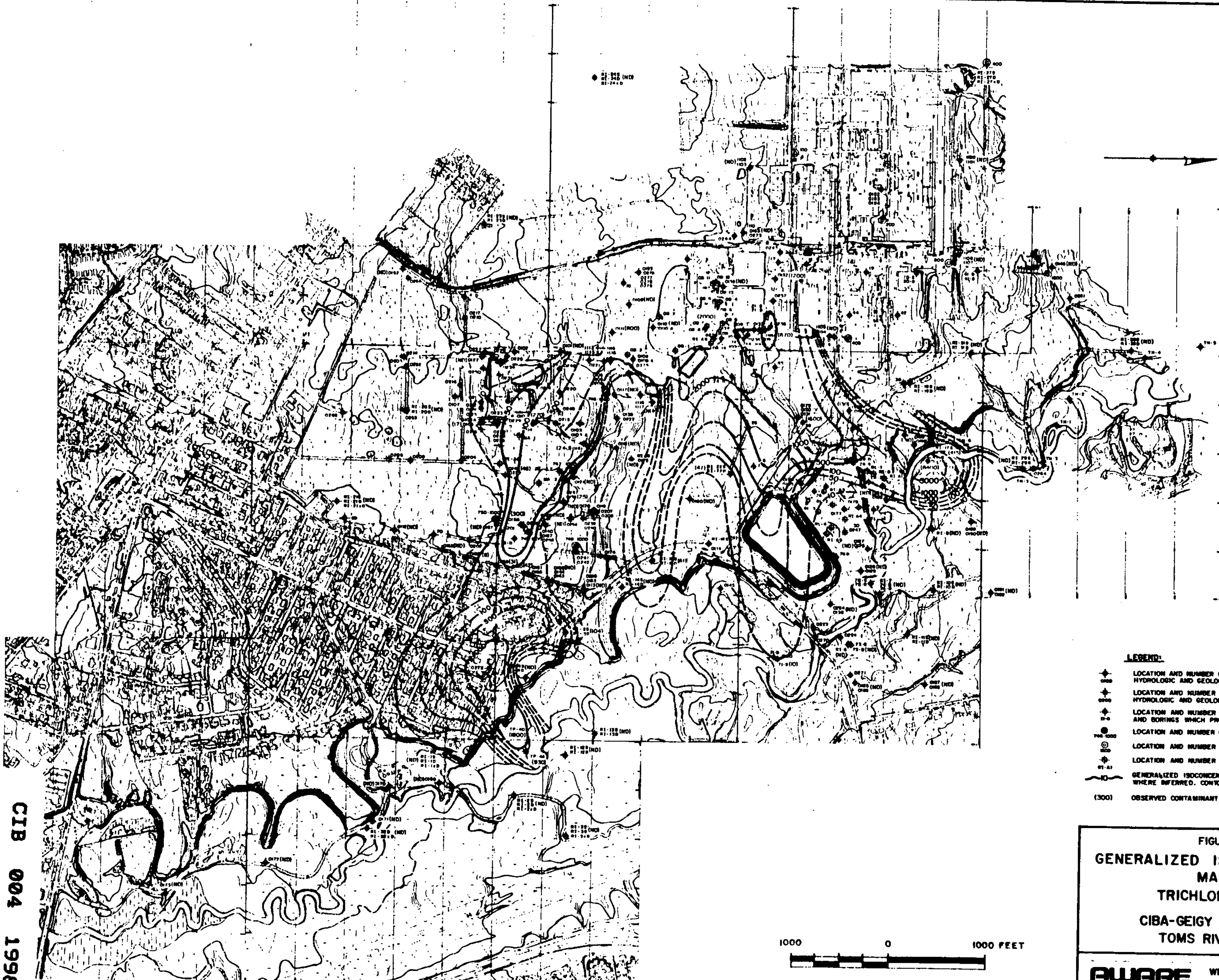


FIGURE 4-47

GENERALIZED ISOCONCENTRATION MAP OF TVPP IN THE PRIMARY COHANSEY

CIBA-GEIGY CORPORATION
TOMS RIVER PLANT

AWARE INCORPORATED
WEST MILFORD, NEW JERSEY
NASHVILLE, TENNESSEE



LEGEND:

- LOCATION AND NUMBER OF MONITORING WELLS WHICH PROVIDE HYDROLOGIC AND GEOLOGIC INFORMATION
- LOCATION AND NUMBER OF PIEZOMETERS WHICH PROVIDE HYDROLOGIC AND GEOLOGIC INFORMATION
- LOCATION AND NUMBER OF MONITORING WELLS, PIEZOMETERS, AND BORINGS WHICH PROVIDE ONLY GEOLOGIC INFORMATION
- LOCATION AND NUMBER OF PURGE WELLS
- LOCATION AND NUMBER OF PRODUCTION WELLS
- LOCATION AND NUMBER OF AUGER BORINGS
- —10— GENERALIZED ISOCONCENTRATION CONTOUR, IN PPB. DASHED WHERE INFERRED. CONTOUR INTERVAL IS VARIABLE
- (300) OBSERVED CONTAMINANT CONCENTRATION IN PPB

FIGURE 4-48

GENERALIZED ISOCONCENTRATION MAP OF TRICHLOROETHENE

CIBA-GEIGY CORPORATION TOMS RIVER PLANT

AWARE INCORPORATED

WEST MILFORD, NEW JERSEY
NASHVILLE, TENNESSEE

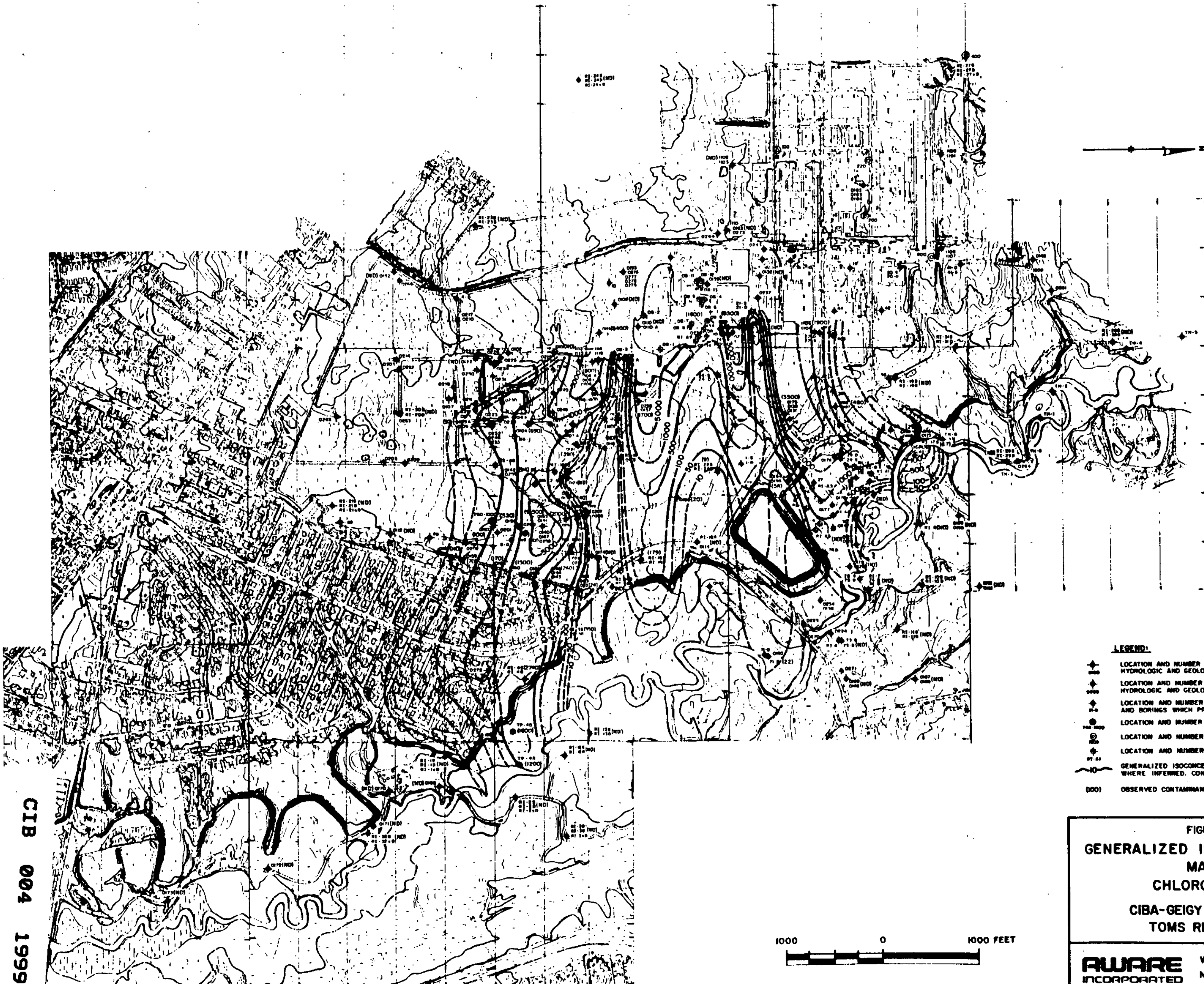


FIGURE 4-49
GENERALIZED ISOCONCENTRATION MAP OF CHLOROBENZENE
CIBA-GEIGY CORPORATION
TOMS RIVER PLANT

AWARE INCORPORATED
WEST MILFORD, NEW JERSEY
NASHVILLE, TENNESSEE

CIB 004 1999

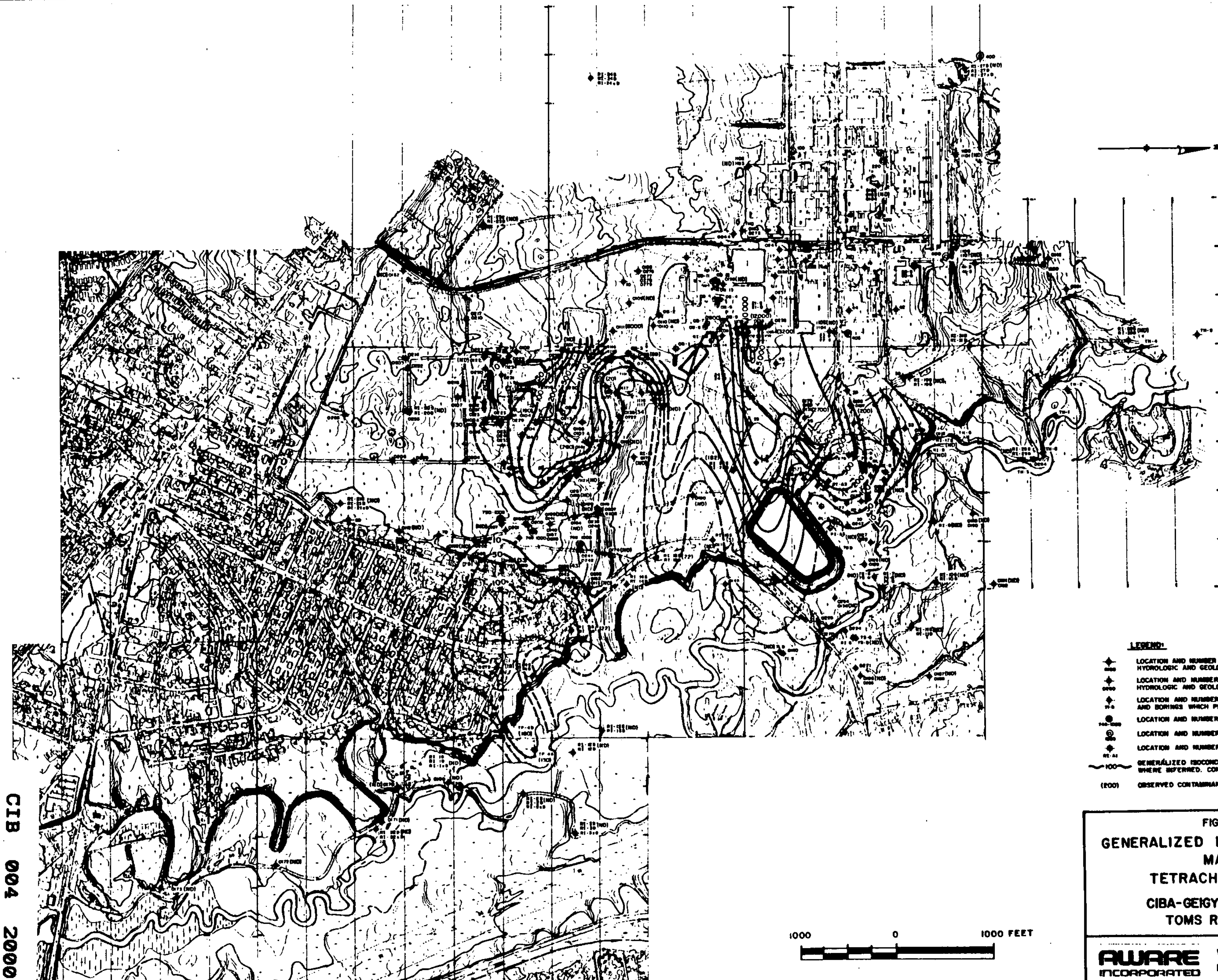


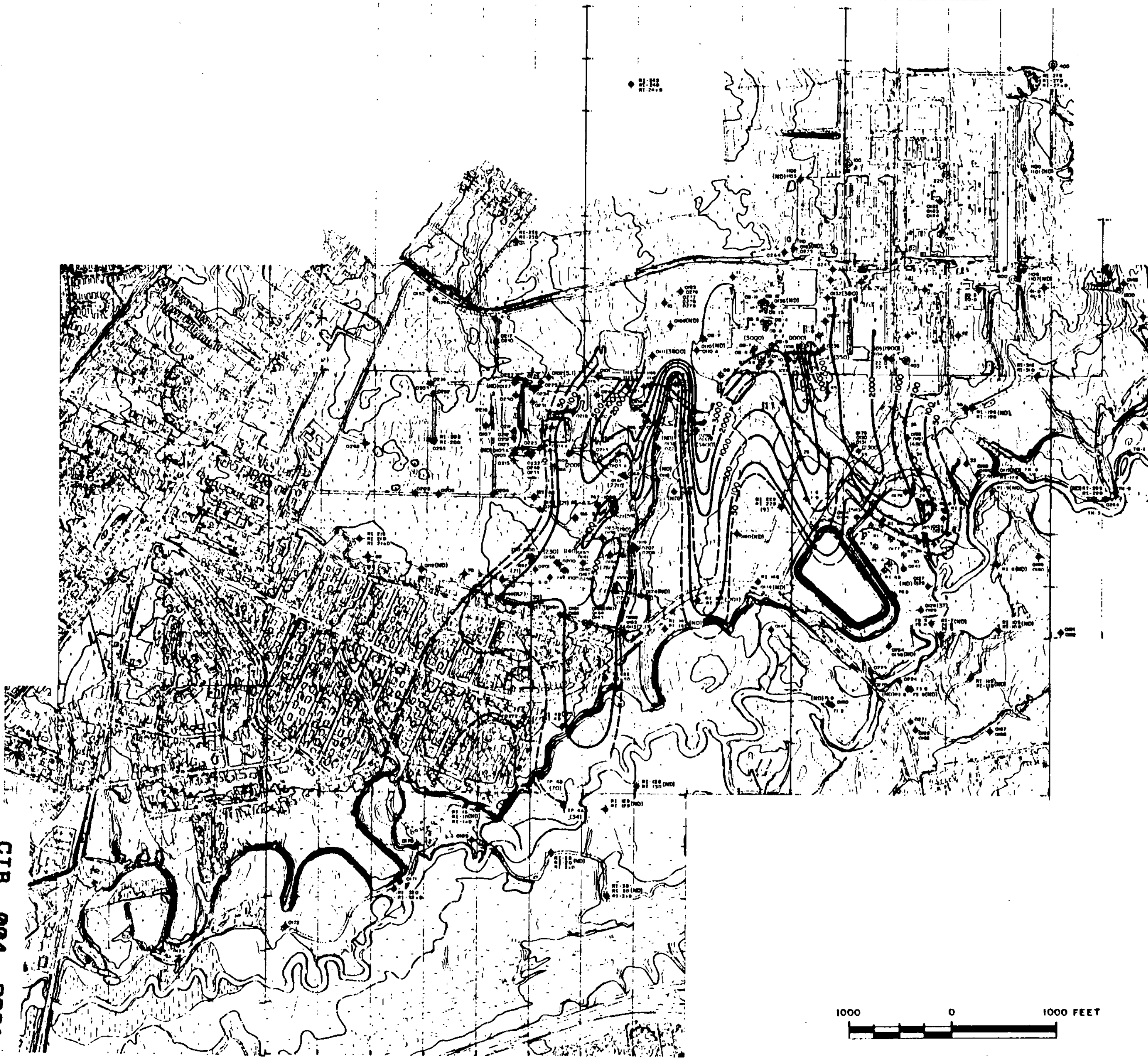
FIGURE 4-50

GENERALIZED ISOCONCENTRATION MAP OF TETRACHLOROETHENE

CIBA-GEIGY CORPORATION TOMS RIVER PLANT

AWARE INCORPORATED
WEST MILFORD, NEW JERSEY
NASHVILLE, TENNESSEE

CIB 004 2000



LEGEND:

- LOCATION AND NUMBER OF MONITORING WELLS WHICH PROVIDE HYDROLOGIC AND GEOLOGIC INFORMATION
- LOCATION AND NUMBER OF PIEZOMETERS WHICH PROVIDE HYDROLOGIC AND GEOLOGIC INFORMATION
- LOCATION AND NUMBER OF MONITORING WELLS, PIEZOMETERS, AND BORINGS WHICH PROVIDE ONLY GEOLOGIC INFORMATION
- LOCATION AND NUMBER OF PURGE WELLS
- LOCATION AND NUMBER OF PRODUCTION WELLS
- LOCATION AND NUMBER OF AUGER BORINGS
- GENERALIZED ISOCONCENTRATION CONTOUR, IN PPB. DASHED WHERE INFERRED. CONTOUR INTERVAL IS VARIABLE
- (180) OBSERVED CONTAMINANT CONCENTRATION IN PPB

FIGURE 4-51

GENERALIZED ISOCONCENTRATION MAP OF 1,2 - DICHLOROBENZENE

CIBA-GEIGY CORPORATION
TOMS RIVER PLANT

AWARE INCORPORATED — WEST MILFORD, NEW JERSEY; NASHVILLE, TENNESSEE

River flood plain as an effective barrier to contaminant migration. It has been demonstrated that groundwater in both the Primary as well as the Lower Cohansey units ultimately discharges to the flood plain in this area and that no further plume migration is occurring.

Another observation worth noting is the close correspondence between the isoconcentration maps for TVPP, chlorobenzene, and trichloroethene. These maps indicate the same general pattern of contaminant concentrations across the site. The trichloroethene isoconcentration map does suggest that the Equalization Basin Area and the Plant Process Area are potentially more active sources of trichloroethene than is the Former Landfill. Nonetheless, the patterns and the general extent of contamination are essentially the same.

The isoconcentration maps for tetrachloroethene and chloride, however, indicate two distinctly different patterns. For example, the map of tetrachloroethene concentrations (Figure 4-50) very clearly indicates a zone of no detectable tetrachloroethene in the vicinity of the Cardinal Drive plant boundary. This zone of non-detectable tetrachloroethene appears to be associated with the recovery well system that operates in this area. Downgradient of the plant boundary, tetrachloroethene is again present in the aquifer. The resultant pattern of isoconcentration contours suggests that the plume of tetrachloroethene has separated along a line that parallels the plant boundary and the recovery well system. The isoconcentration map for trichloroethene exhibits a similar constriction of the plume in this same area, although complete separation has apparently not occurred. If these phenomena are, in fact, attributable to the operation of the purge system, one would hypothesize that significant quantities of uncontaminated water are being drawn upward from the Kirkwood Formation. Without such recharge from below, plume separation could not occur.

The apparent extent of tetrachloroethene contamination to the north is also noteworthy. For example, tetrachloroethene does not appear to be significantly associated with the portion of the plume emanating from the Process Area. The Equalization Basin Area, on the other hand, appears to be a major source of tetrachloroethene. Finally, tetrachloroethene is one of the few major organic compounds considered diagnostic of the site waste stream that was not detected in monitoring well RI-9 located across the Toms River from the plant site.

The isoconcentration map for chloride is similar in many respects to the map of TVPP. The maps differ, however, in the apparent southeastern limit of contamination. Figure 4-45, for example, clearly suggests the presence of contamination extending from the vicinity of monitoring well 744-0142 southeast of the Former Sludge Disposal Area towards monitoring well 744-0112 located to the southeast along the Cardinal Drive plant boundary. A similar pattern is noted on the terrain conductivity isopleth map (Figure 4-44). Elevated sulfate concentrations are also associated with monitoring well 744-0112. Volatile priority pollutants were not detected in this well, hence the absence of this feature on the TVPP isoconcentration map. Historically, however, relatively low concentrations of volatile priority pollutants (<40 ppb) have been detected in this well.

A linear band of apparently "clean" groundwater, located between the Cardinal Drive and Oak Ridge Parkway portions of the plume, appears on each of the isoconcentration maps (Figures 4-45 through 4-51) and is suggested on the terrain conductivity isopleth map (Figure 4-43). This feature is defined by numerous monitoring wells and very clearly coincides with the location of a major drainage swale that receives run-off from a large portion of the site. Moreover, the drainage swale generally overlies the linear gap in the "yellow clay" unit described previously. It appears that a number of these factors have been combined to produce the area essentially of uncontaminated groundwater.

Prior to this investigation, many of the monitoring wells that now are uncontaminated and are located in or adjacent to the drainage swale, exhibited significant levels of contamination. In fact, isoconcentration maps drawn using historical data suggest that the axis of contamination was previously located further to the north, closer to the drainage swale. Several factors may have contributed to this phenomenon.

First, the installation of a cap on the Former Landfill probably has reduced to a degree the rate at which contaminants are leached to the groundwater table. With the installation of the cap, additional surface runoff is now discharged to the drainage swale and is presumably of good quality. As previously described, surface runoff only rarely leaves the site. The drainage swale thus serves essentially as a collector of runoff that then recharges to the groundwater system. Finally, the groundwater recovery well system was installed just to the south of the swale. Together these three factors: capping the landfill, recharge from surface runoff, and recovery system pumping probably combine to create the zone of relatively clean groundwater.

<u>Upper Cohansey Water-Bearing Zone</u>

The Upper Cohansey water-bearing zone is of relatively little significance on a site-wide basis, since it occurs only locally. Where it does occur, however, it likely plays a role in the patterns of contaminant migration. For example, in the vicinity of the former landfill we have encountered the Upper Cohansey as a very thin zone of saturation that appears to be locally very highly contaminated. We have measured up to 250 ppm of trace volatile gases in samples from this zone using the HNU photoionization analyzer. To date, few monitoring wells have been installed in this zone. However, the contamination that is present ultimately reaches the Primary Cohansey. Although the need for additional investigation of this unit is not foreseen, it is recommended that it be considered in the assessment of potential remedial measures.

<u>Evaluation of Cardinal Drive Purge Well System</u>

Five purge wells (746-1000 through 750-1000) were installed in December 1984, in the vicinity of Cardinal Drive in order to prevent further off-site contamination migration in the Primary Cohansey Sand. The effectivenss of this system has been evaluated by determinating the extent of plume capture from water table elevations measured in the vicinity. The first task consisted of tabulating withdrawal rates from each of the five purge wells over a five and one-half month period beginning January 1, 1986. This data has been summarized below:

Purge Well	Average Withdrawal (gpd)
746-1000 (#1)	64,593
747-1000 (#2)	93,039
748-1000 (#3)	54,759
749-1000 (#4)	94,340
750-1000 (#5)	56,079
Total Average Withdrawal (gpd) (January 1 through June 15, 1986)	362,810

The effectiveness of the Purge System for plume capture was then evaluated via water level measurements at all available monitoring wells and piezometers completed in the Cohansey. Measurements were made by AWARE on June 18-20, 1986 and have been contoured on Figure 4-52. The data includes two recently installed piezometers (0280 and 0281) located between Purge Wells 748-1000 and 749-1000. These piezometers were installed for the expressed purpose of confirming the development of a continuous trough of drawdown in this area. As illustrated on Figure 4-52 a continuous trough in the vicinity of wells 748-1000, 749-1000 and 750-1000 is demonstrated by the field data. The resulting capture zone is illustrated to be of sufficient width to intercept the limits of groundwater contamination in this area. Furthermore, a groundwater divide has been created between these three purge wells and the site boundary (Cardinal Drive) such that a groundwater reversal (groundwater flow to the west) is occurring. This phenomenon clearly demonstrates that the purge wells are effective and no further off-site contaminant migration is occurring in this area.

Contamination at Monitoring Well RI-9

During the field investigation conducted by USEPA/NUS, an off-site groundwater monitoring well was installed on the east side of the Toms River (Figure 4-1). The well (RI-9), screened in the Primary Cohansey, was subsequently sampled and found to contain over 10,000 ppb Total Volatile Priority Pollutants (TVPP). Additional investigations were conducted by AWARE Inc. in order to determine the extent and hydrodynamics of plume migration in this area. The results are discussed in the following paragraphs.

In accordance with the basic principals governing groundwater flow, groundwater within the Primary and Lower Cohansey units flow from areas of higher water table elevation to areas of lower elevation. Inasmuch as Toms River represents the lowest water table elevation in the RI-9 Area, groundwater in the Primary Cohansey unit flows towards and discharges into the river channel. This discharge condition is illustrated on Figure 4-42 and consists of equal components from the east as well as the west meeting at the river channel. Groundwater within the Lower Cohansey must also ultimately discharge into the Toms River channel but due to the intervening Cohansey/Kirkwood Transitional Unit of lower hydraulic conductivity the flow lines are diverted before discharge to the river channel can occur. More specifically, water in this lower aquifer must first "discharge" through the intervening aquitard and enter the Primary Cohansey flow system prior to stream discharge.

With these factors in mind, a conceptual model of groundwater flow indicates that the location of discharge from the Lower to the Primary Cohansey is less

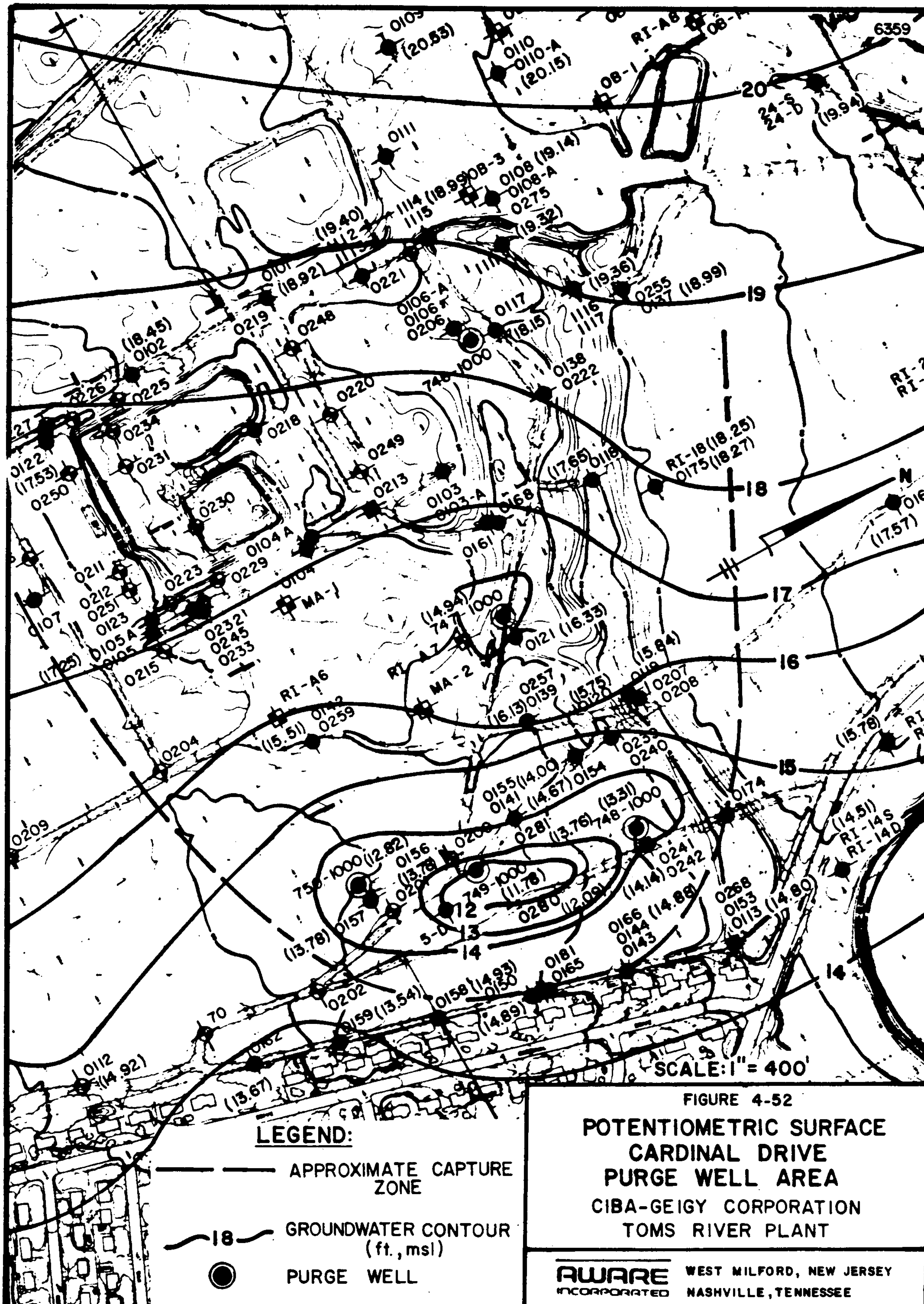


FIGURE 4-52

POTENTIOMETRIC SURFACE
CARDINAL DRIVE
PURGE WELL AREA

CIBA-GEIGY CORPORATION
TOMS RIVER PLANT

AWARE INCORPORATED WEST MILFORD, NEW JERSEY NASHVILLE, TENNESSEE

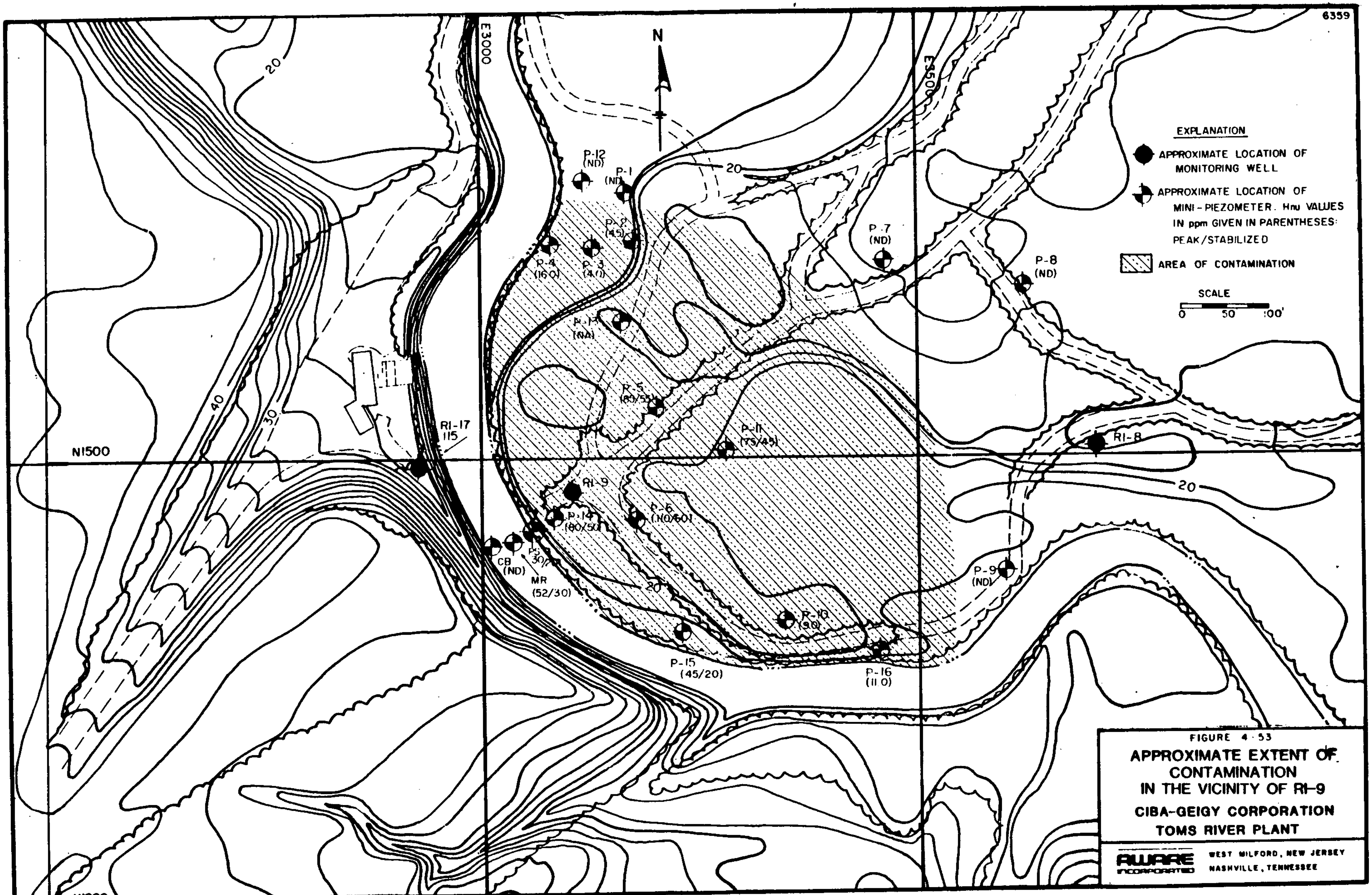


FIGURE 4-53
APPROXIMATE EXTENT OF CONTAMINATION IN THE VICINITY OF RI-9
CIBA-GEIGY CORPORATION TOMS RIVER PLANT

AWARE INCORPORATED WEST MILFORD, NEW JERSEY NASHVILLE, TENNESSEE

CIB 004 2006

fig 4-53

dependent upon river channel location, but rather, is governed by a more regional influence. Consequently, from a regional perspective, the entire width of the Toms River flood plain would be considered as a discharge zone. This concept becomes critical in the RI-9 Area in light of the meander of the river channel to the west within the river valley. It would be expected therefore that discharge from the Lower Cohansey to the Upper Cohansey would occur east of the river channel near the center of the river valley.

The results of the mini-piezometer survey are depicted on Figure 4-53, which indicates the peak and stabilized HNU responses at each sampling location as well as the inferred extent of the contamination. It is interesting to note that the axis of the inferred plume is approximately centered upon well RI-9 and decreases to the north, northeast and east. If the contamination originated from an off-site source to the north or east of well RI-9, one would anticipate values increasing in these directions rather than decreasing as was observed. This suggests that groundwater contamination near RI-9 originates from the west, i.e., from within the Ciba-Geigy plant site.

Based on water quality data from monitoring wells, HNU response at the mini-piezometer locations and groundwater flow dynamics, a conceptual model for contaminant occurrence and movement in the RI-9 Area is developed. The objective of this model is to evaluate the potential source areas for the observed contaminant migration in the RI-9 Area. To facilitate this evaluation, contaminant migration in the Primary as well as the Lower Cohansey aquifers is discussed.

As can be inferred from the groundwater contours on Figure 4-42, groundwater contamination west of the river channel originates from the Ciba-Geigy site in the vicinity of the southern portion of the Plant Process Area. Owing to the equal component of horizontal flow from the east, the fate of these contaminants is direct discharge to the Toms River channel. The channel serves as an effective hydrologic barrier and thus no further migration of this plume is occurring beyond the Toms River or the Ciba-Geigy property line.

As can also be inferred from Figure 4-42, groundwater originating in the vicinity of the Equalization Basins discharges into the Toms River nearly a mile downstream of RI-9. Groundwater contamination originating near the Equalization Basin therefore does not migrate toward RI-9 nor does it leave the Ciba-Geigy property.

Groundwater contamination observed in the Primary Cohansey east of the river channel (RI-9) does not share a similar origin (source area) as that west of the river. This scenario is supported by the sharp difference (increase) in concentration on the east side of the river (10 ppm in RI-9) and by the groundwater flow dynamics of the system.

This contamination is clearly not from the Primary but from the Lower Cohansey aquifer via deferred upward discharge east of the river channel. Once in the Primary Cohansey, the natural westward flow component results in the eventual discharge to the Toms River. Thus, the areal extent of contamination both in the Primary and Lower Cohansey aquifers has reached a condition in which no further advancement of the plume is occuring.

The distribution of groundwater contamination within the Lower Cohansey is illustrated on Figure 4-46. Concentrations of over 20 ppm were observed (Well 744-0115) just west of the river channel, which are similar in range to those found east of the river (10 ppm in RI-9). As stated previously, the flow of this contamination is not directly to the river channel but first to the Primary Cohansey east of the channel and then subsequently to the river channel.

Estimate of Groundwater Volume and Mass of Contaminants

The extent and magnitude of groundwater contamination in the Cohansey water-bearing units has been illustrated using the Total Volatile Priority Pollutant (TVPP) concentrations (Figures 4-46 and 4-47) as well as selected individual constituents (Figures 4-48 through 4-51). Although generally similar in shape and concentration each of these maps illustrates a slightly different portrayal of the magnitude of groundwater contamination. In order to more fully evaluate these differences, the volume of groundwater and the mass of the respective contaminant (or sum of contaminants in the case of TVPP) has been estimated and is presented on Table 4-31). It should be noted that these estimates include only the dissolved fraction of the contaminants.

In these calculations, it has been estimated that throughout the Primary Cohansey Sand, the plume is approximately 30 feet thick and has a porosity of 0.30. Concentrations of the various constituents in groundwater were taken directly from the isoconcentration contour maps presented as Figures 4-46 through 4-51. The thickness and porosity of the Lower Cohansey Sand was estimated to be 20 feet and 0.30 respectively. It has also been assumed that wherever contamination exists in the Lower Cohansey Sand, the overlying Cohansey/Kirkwood Transitional Unit is similarly contaminated. The average thickness of this unit has been assumed to be 20 feet and its porosity is estimated to be 0.40.

Table 4-31 reveals that the Primary Cohansey Sand contains approximately 1.1 billion gallons of groundwater with total volatile priority pollutant levels above 10 parts per billion. In the Lower Cohansey Sand, there is an additional 430 million gallons of groundwater with total volatile priority pollutant levels exceeding 10 parts per billion. The total mass of total volatile priority pollutants within the Primary Cohansey Sand is estimated to be 27,000 pounds. In the Lower Cohansey Sand, there are approximately 19,000 pounds of total volatile priority pollutants. The mass of several individual constituents, specifically trichlorethene, chlorobenzene, tetrachloroethene, and 1,2-dichlorbenzene are also presented in the table.

TABLE 4-31

ESTIMATE OF GROUNDWATER VOLUME AND MASS OF CONTAMINANTS IN PLUMES

Constituent	Figure in Which Constituent Is Depicted	Volume of Groundwater (gallons)	Mass of Contaminant (pounds)
Primary Cohansey Sand			
Total Volatile Priority Pollutants (TVPP)	4-47	1,100,000,000	27,000
Trichloroethene	4-48	670,000,000	3,300
Chlorobenzene	4-49	820,000,000	8,000
Tetrachloroethene	4-50	700,000,000	4,000
1,2-Dichlorobenzene	4-51	670,000,000	5,300
Lower Cohansey Sand			
Total Volatile Priority Pollutants (TVPP)	4-46	430,000,000	19,000

5.0 FACTORS RELEVANT TO REMEDIAL ACTION

The Hydrogeologic and Related Environmental Investigation has described the character of the Toms River Plant hydrogeologic regime and defined the spatial extent of soil and groundwater contamination within that system. The investigation has also examined the potential contaminant source areas and has described the nature and migratory patterns of the contamination. There are, inevitably, aspects of these findings which bear heavily upon the viability of various remedial technologies. It is the objective of this section of the investigation report to describe the hydrogeologic findings which will be of most significance in determining appropriate site remediations.

Toms River Hydrogeologic Boundaries

The investigation has shown that the Toms River and its associated flood plain serve as a hydrogeologic boundary for groundwater flow within the Cohansey Sand aquifer. Groundwater flow within the Cohansey Sand, on both the east and west sides of the Toms River, discharges to the river and the adjacent marsh areas. Consequently, the plume of groundwater contamination emanating from the Ciba-Geigy site ultimately discharges to the Toms River and the adjacent marsh area.

Sampling and analysis of the Toms River water has shown that the Toms River Plant has a negligible impact upon surface water quality in the Toms River. No organic compounds were found above the detection limit in 12 water samples collected by NUS and 4 water samples collected by Environ. Several surface water stations suggest that iron, sodium, and calcium may be slightly elevated with respect to upstream conditions, however, this may be a natural phenomenon.

More important, however, is the fact that as a result of the discharge to the Toms River, the plume's northeastward migration has been arrested, and thus no further plume advancement is occurring. In this condition, the plume is not continuing to contaminate additional areas of the Cohansey aquifer, nor does it pose a threat to water supplies lying east of the Toms River.

Kirkwood Formation Aquitard

The investigation has revealed that the Cohansey Sand aquifer is underlain by an aquitard which is part of the Kirkwood formation. The aquitard is in excess of 100 feet thick, consists of several distinct units, and has a permeability more than 100 times less than that of the overlying Cohansey Sand. It has also been determined that much of the site groundwater flow through the aquitard is vertically upward, representing discharge conditions. As a result of these aforementioned factors, the plume of groundwater contamination has thus far been found to be restricted to the Cohansey Sand aquifer. Groundwater recovery systems can therefore be confined to the Cohansey Sand aquifer.

Kirkwood No. 1 Sand

No evidence of groundwater contamination in the No. 1 Sand of the Kirkwood formation has been found. In fact, groundwater dating using naturally occurring tritium suggests that the groundwater in the No. 1 Sand predates the inception of the Toms River Plant. To facilitate the collection of additional data in the No. 1 Sand, a field investigation has been developed and is currently being undertaken by AWARE. The investigation is limited primarily to the northern portion of the site where downward vertical gradients were measured and contamination in the Lower Cohansey has been documented, and consists of the installation of five additional monitoring wells in the Kirkwood No. 1 Sand.

Dense Non-Aqueous Phase Liquids Contamination

The actual or potential presence of soil contamination resulting from the vertical migration of dense non-aqueous phase liquids has been indicated in several of the source areas, both above and below the groundwater table. Pooled dense non-aqueous phase liquids constituting distinct sources of contamination, non-contiguous with historical sources may also exist, although direct evidence has not been uncovered in the investigation. (It is not surprising that direct evidence of pooled dense non-aqueous phase liquids was not found. Pooled dense non-aqueous phase liquids tend to be localized and of limited areal extent). Decontamination of the residual dense non-aqueous phase liquids from soil requires considerably more effort per cubic foot of aquifer than contamination in the downgradient plume. The plume itself contains only relatively low levels of contamination which would have partitioned between the groundwater and the aquifer skeleton. This contamination can be flushed from the aquifer with relatively few pore volume exchanges under normal circumstances. However, where dense non-aqueous phase liquids exist, it may require upwards of 100 pore volume exchanges of groundwater before this contamination is sufficiently removed from the aquifer.

6.0 CONCLUSIONS

By way of summary, the following conclusions regarding the hydrogeologic and environmental conditions at the Toms River Plant site can be drawn:

1. A preliminary risk assessment has been conducted by Environ to characterize the potential risks to public health and the environment which may result from the discharge of contaminated groundwater from the Toms River Plant of Ciba-Geigy Corporation. The results are contained in a separate document entitled "Preliminary Assessment of the Risks Associated with the Ground-Water Contamination at the Toms River Plant." Environ concludes that there is no evidence that significant risk to public health would result from foreseeable exposure to contaminants migrating in groundwater from the Toms River Plant, as characterized to date, even if no remedial measures were to be instituted.

2. The plant site is underlain by a sequence of unconsolidated sediments consisting primarily of the Cohansey Sand, and the Kirkwood, and Shark River/Manasquan Formations. The Cohansey Sand and Kirkwood Formations represent the primary formation of interest. The Primary Cohansey Water-Bearing Zone is the thickest and most areally extensive of the various water-bearing zones.

3. The Cohansey Sand Formation serves as a significant aquifer in the Toms River region. Groundwater contained within the Cohansey discharges primarily to the Toms River and the associated flood plain. It has been demonstrated that the Toms River and its associated flood plain serve as a hydrogeologic barrier to northeasterly flow of groundwater within the Cohansey Sand aquifer.

4. The Kirkwood Formation forms a continuous aquitard of relatively low permeability beneath the site and serves to restrict, to a degree, the vertical movement of contaminants. The Kirkwood Formation can be subdivided into two water-bearing zones and three interbedded aquitards. The two water-bearing zones have been termed the No. 1 and No. 2 Sands.

5. A plume of groundwater contamination has been found at the Toms River site, stretching from a north/south trending line of source areas to the Toms River. The plume encompasses a total area of approximately 375 acres.

6. The composite plume is principally found within the Primary and Upper Cohansey Sand aquifer. The plume also occupies a portion of the Lower Cohansey aquifer. A variety of contaminants or indicators of contamination have been detected within the plume, and consists largely of volatile organic compounds, as well as base/neutral extractable compounds. The inorganic constituents include chloride, sulfate, total dissolved solids and specific conductance.

7. The portion of the plume within the Lower Cohansey Sand Aquifer extends from the southern portion of the Process Area eastward to the Toms River, covering an area of approximately 100 acres. The Lower Cohansey plume discharges fully to the Toms River and its associated flood plain. However, in the area of RI-9, the plume passes the center line of the Toms River due to the combined effects of the westward meander of the river in this area and the semi-confining properties of the Cohansey/Kirkwood Transitional Unit. As a result of the discharge of the plume to the Toms River, its eastward migration has been halted.

8. Sampling and analysis of the Toms River water has shown that the Toms River Plant has a negligible impact on the surface water quality in the Toms River. Priority pollutant organics were not found above the detection limit with the exception oftrichloroethane which was found at several stations at concentrations below the detection limit. The analysis of NUS sample SW-6 indicated a concentration of 5.6 ppb. Several surface water stations suggest that iron, sodium, and calcium may be slightly elevated with respect to upstream conditions; however, this may be a natural phenomenon. Surface water and sediment samples were also collected under the direction of Environ in an area of groundwater discharge in the marshland area of Winding River Park. These samples indicate the presence of volatile organic contamination of surface water and sediment in an area which coincides with the highest isoconcentration contours of total volatile priority pollutants. One stream bed sediment sample in the vicinity of RI-9 also indicated volatile organic contamination as a result of contaminated groundwater discharge.

9. No groundwater contamination has been detected in either the No. 1 or No. 2 Sands of the Kirkwood Formation. In fact, groundwater dating employing the naturally-occurring environmental isotope, tritium, indicates that the groundwater within the Upper No. 1 Sand predates inception of the Toms River Plant operations.

10. Beneath a number of contaminant source areas, particularly the Former Landfill, the Treatment Plant Area, and the Former Fire Prevention Training Area, the presence of soil contamination as a result of the migration of dense non-aqueous phase liquids is directly and indirectly evidenced.

11. Five purge wells were activated in January 1985, on its property near the Cardinal Drive boundary in order to prevent further off-site contaminant migration in the Primary Cohansey Sand. The effectiveness of the Purge System for plume capture has been evaluated via water level measurements at all available monitoring wells and piezometers completed in the Cohansey. The resulting capture zone is determined to be of sufficient width to intercept the general limits of groundwater contamination in this area. Furthermore, a groundwater divide has been created between the three easternmost purge wells and the site boundary (Cardinal Drive) such that a groundwater reversal (groundwater flow to the west) is occurring. This phenomenon clearly demonstrates that the purge wells are effective and no further off-site contaminant migration is occurring in the area.

12. The factors believed to be most significant to the selection of a site-wide remediation are as follows:

- The Toms River and its associated flood plain serve as a hydrogeologic boundary for groundwater flow in the Cohansey sand aquifer.
- The Toms River Plant site is continuously underlain by an aquitard which is part of the Kirkwood formation.
- No evidence of groundwater contamination in the Kirkwood No. 1 Sand has been found. Five additional wells have been installed in the Kirkwood No. 1 Sand for monitoring purposes.
- The presence of non-aqueous phase liquids has been indicated.

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