NUS CORPORATION
A Halliburton Company

100

235916

REMEDIAL INVESTIGATION
FOR THE CIBA-GEIGY SITE
TOMS RIVER, DOVER TOWNSHIP
OCEAN COUNTY, NEW JERSEY

FIELD INVESTIGATION TEAM ACTIVITIES AT UNCONTROLLED HAZARDOUS SUBSTANCES FACILITIES — ZONE I

NUS CORPORATION
SUPERFUND DIVISION

R-584-06-86-06
REV. 3

REMEDIAL INVESTIGATION FOR THE CIBA-GEIGY SITE TOMS RIVER, DOVER TOWNSHIP OCEAN COUNTY, NEW JERSEY

PREPARED UNDER
TECHNICAL DIRECTIVE DOCUMENT NO. 02-8707-16
CONTRACT NO. 68-01-7346

FOR THE

ENVIRONMENTAL SERVICES DIVISION
U.S. ENVIRONMENTAL PROTECTION AGENCY

JANUARY 22, 1988

NUS CORPORATION
SUPERFUND DIVISON

SUBMITTED BY:

William G. Russell
WILLIAM G. RUSSELL
FIT PROJECT MANAGER

APPROVED:

Ronald M. Naman
RONALD M. NAMAN
FIT OFFICE MANAGER

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd)

TABLE OF CONTENTS (Cont'd)

TABLE OF CONTENTS (Cont'd)

TABLE OF CONTENTS (Cont'd)

TABLE OF CONTENTS (Cont'd)

APPENDICES (Cont'd)

TABLES

TABLES (Cont'd)

TABLES (Cont'd)

FIGURES

FIGURES (Cont'd)

EXECUTIVE SUMMARY

In August 1984, NUS Region 2 FIT was directed by the United States Environmental Protection Agency (U.S. EPA) to develop a Work Plan for a Remedial Investigation of the Ciba-Geigy Toms River Chemical Company Site located in Dover Township, New Jersey. The Work Plan was submitted to the U.S. EPA in December 1984 and approved shortly thereafter. The Remedial Investigation work was authorized under U.S. EPA contract number 68-01-6699, Technical Directive No. 02-8408-04. Following U.S. EPA approval of the Site Operations Plan in 1985, the on-site investigations were initiated. After the on-site investigation work was completed in October 1985, data analysis and writing of the Remedial Investigation Report began. In 1986 the U.S. EPA contract number 68-01-6699 expired. A new contract was agreed upon between the U.S. EPA and NUS Corporation. Under the new U.S. EPA contract, number 68-01-7346, a new Technical Directive, number 02-8707-16, was issued to NUS for revising the Remedial Investigation, Feasibility Study, and other related work.

Site Background

The Ciba-Geigy Site (latitude 39° 59' 19" N, longitude 74° 21' 50" W) is located on Route 37 in Dover Township, Ocean County, New Jersey. Three hundred and twenty acres of the 1,275-acre site are developed; the remainder is forested. The manufacturing facilities at Ciba-Geigy are comprised of 30 major buildings, a wastewater treatment plant with a maximum capacity of 9.3 million gallons per day (MGD), and a lined reservoir for emergency storage of untreated and treated wastewater.

The Toms River forms the northeastern boundary of the site. Winding River Park, an outdoor recreational area situated on the floodplain of the Toms River, adjoins the site to the east and southeast. The site is bounded on the west by an industrial park, and on the south by residential and commercial properties. Major residential developments, including two planned-retirement communities, are located 1 mile south of the site. The business district of the town of Toms River lies 3 miles southeast of the site.

Ciba-Geigy began construction at the site in 1950 and production in 1952. Ciba-Geigy was then known as the Toms River Division of Ciba States Limited, producing vat dyestuffs and epoxy resins by the Bisphenol A process. In 1960, Toms River Division of Ciba States Limited merged with Cincinnati Chemical Works, Incorporated, and became Toms River Chemical (TRC). Cincinnati Chemical, owned by the Swiss firms of Ciba Limited, J.R. Geigy, S.A., and Sandoz Limited, produced azo dyestuffs and intermediates. The manufacturing operations of Cincinnati Chemical were moved to the Ciba-Geigy Site; Ciba, Geigy, and Sandoz became co-owners of Ciba-Geigy. In the mid 1970s, Ciba merged with Geigy to become Ciba-Geigy. Sandoz sold its interest within the next few years and, in 1981, Toms River Chemical, a subsidiary of Ciba-Geigy, merged with the Ciba-Geigy Corporation (CAI, 1983). It has been reported that Ciba-Geigy's future plans for the site include a phasing out of the current operations and a shift towards pharmaceuticals production.

Manufacturing processes at Ciba-Geigy generate both liquid and solid wastes. Liquid wastes are treated prior to discharge to the Atlantic Ocean. Solid wastes, consisting of residues from manufacturing processes and sludges from on-site wastewater treatment, have been disposed of either in bulk or in drums in on-site landfills. At the present time, drummed wastes are being disposed of off site. Wastewater treatment sludge is being stockpiled atop a closed cell of the Active Landfill.

Following is a list of known past or present disposal areas for wastes at the Ciba-Geigy chemical plant in Toms River:

- Backfilled Lagoons
- Drum Disposal Area
- Lime Sludge Disposal Area
- Filtercake Disposal Area
- Wastewater Treatment Plant Area
- Active Landfill
- Former Calcium Sulfate Disposal Area

In addition to the known disposal areas, the following areas at Ciba-Geigy have also been identified as possible repositories of past-generated waste:

- Production Area
- Compactor Area
- Former Fire Prevention Training Area
- Wastewater Treatment Plant Pipeline
- Borrow Area
- Suspected East Overflow Area
- Casual Dumping Area

Summary of Work Efforts

The following major tasks were accomplished by NUS Corporation during the RI:

- Preexisting geological, geophysical, hydrological, and chemical information was reviewed and evaluated.

- Eight boreholes were driven in identified waste-disposal areas, and the wastes were sampled, analyzed, and characterized. Waste volumes were calculated, and the impact of the waste deposits on groundwater, surface water, and biological systems was assessed.

- Fifty-nine monitoring wells were installed, and the subsurface data generated during drilling were employed to determine and define the geology of the site area.

- A program of water-level measurements was instituted to provide a basis for determining the hydrology of the site area and specifically to determine the effectiveness of the Toms River as a groundwater barrier.

- The bail test was performed on 30 wells. With these data, the horizontal hydraulic conductivities of sediments surrounding the well screens were determined. This information is used to help model groundwater flow and better characterize migration of contaminants.

- Ground penetrating radar and terrain conductivity surveys were conducted site-wide.

- Groundwater from the 59 EPA wells and selected Ciba-Geigy wells was sampled and analyzed in August 1985, October 1985, February 1986, June 1986, and September 1986.

- One hundred and eighty-nine shallow soil samples were collected and analyzed for HSL parameters, indicator parameters, and dioxin to characterize contamination of on-site soils.

- Surface water, stream-bottom sediment, and insect populations were sampled at each of five locations adjacent to the site to determine the impact of the site on these systems.

- A baseline quantitative public health evaluation was performed to determine the impact of human exposure to contaminants.

Other investigations were conducted by Ciba-Geigy consultants. Information from these investigations was used to supplement the data gathered for this remedial investigation.

Conclusions of the Remedial Investigation

The major conclusions of the Remedial Investigation are as follows:

- The Backfilled Lagoons and the Filtercake Disposal Area contain large volumes of sludge; the presence of buried drums is also indicated. These facilities are unlined, and the sludges contain significant concentrations of hazardous substances which are contributing to contamination of the shallow groundwater.

- The Drum Disposal Area as an inactive facility continues to generate the uncontrolled release of hazardous substances to the underlying groundwater. A close correlation between groundwater contaminants and reported predisposal waste analyses gives a general characterization of the waste. In addition, the presence of nonaqueous phase liquids (NAPL) adjacent to the Drum Disposal Area is suspected and must be further characterized.

- Two aquifers were identified at the Ciba-Geigy Site. The first is a water-table aquifer which extends down to approximately -100 feet mean sea level (MSL). The second is a semiconfined aquifer of uncertain thickness extending downward from an elevation of approximately -130 feet MSL. A 30- to 60-foot semiconfining layer separates the two aquifers.

- Three and possibly four source areas for groundwater contamination can be identified. The groundwater contaminant plume originating from the Ciba-Geigy Site is considered to be a composite of several plumes originating from a number of on-site source areas.

- Although the Toms River apparently acts as a sink for groundwater in the water-table aquifer, the semiconfined aquifer is apparently unaffected by the river. However, the effect Toms River has on the semiconfined aquifer has not been conclusively determined due to a lack of wells on the east side of Toms River screened in the semiconfined aquifer.

- Potential off-site contaminant migration is possible in the water-table aquifer at least to the opposite side of the Toms River. The Toms River apparently places no constraints on the migration of contaminants in the lower aquifer. However, this is not conclusive because there is a lack of wells on the east side of Toms River that are screened in the lower aquifer.

- The surface soil results reveal several areas where inorganic contamination is a problem. The inorganics tended to be localized within investigation areas. There is evidence that contaminants are migrating from the contaminated areas via surface water sediments.

- The Toms River has been receiving organic contamination through the upwelling of contaminated groundwater.

- Aquatic insect populations were not found in the surface water at the confluence of Toms River and the Ciba-Geigy cooling water discharge channel.

- Based upon inconclusive results of the biota investigation, no direct correlation can be made between potential contaminant release from the Ciba-Geigy Site and impacts on the aquatic biota of the Toms River.

- The baseline health evaluation for exposure to humans from contaminants emanating from the Ciba-Geigy Site demonstrates that the population will be exposed to an unacceptable carcinogenic risk, and feasible alternatives to lower these contaminant exposures need to be addressed.

The RI Report also identifies areas of further study which must be conducted before all potential environmental impacts from the Ciba-Geigy Site can be resolved. The RI Report does provide data which will be utilized to evaluate remedial alternatives for the management of off-site contaminant migration. The RI Report will also be used to select source control remedies where sufficient data exist.

1.0 INTRODUCTION

In August 1984, NUS Region 2 FIT was directed by the United States Environmental Protection Agency (U.S. EPA) to develop a Work Plan for a Remedial Investigation of the Ciba-Geigy Toms River Chemical Company Site located in Dover Township, New Jersey. The Work Plan was submitted to the U.S. EPA in December 1984 and approved shortly thereafter. NUS Region 2 FIT was directed to proceed with site reconnaissance activities in January 1985. Following U.S. EPA approval of the Site Operations Plan in April 1985, the on-site investigations were initiated. The Remedial Investigation field operations were completed in October 1985.

The objective of the Remedial Investigation is to provide the information required for conducting the Feasibility Study, being prepared under separate cover. Under the Feasibility Study, engineering alternatives for site remediation are evaluated for a variety of criteria including cost, effectiveness, environmental impacts, and regulatory constraints. To facilitate the Feasibility Study process, the Remedial Investigation must

- Characterize on-site wastes and determine the nature, intensity, and distribution of contaminated natural media.
- Delineate on-site waste repositories and determine their relationship to and effect upon the groundwater and surface water systems.
- Delineate off-site contamination relatable to on-site sources and assess the impact upon public health and the environment.
- Determine the need to mitigate the impact of contamination on and in the vicinity of the site.

The first draft Remedial Investigation report was submitted to EPA in June 1986, with two revisions subsequently submitted in August and September 1986, respectively. The third revision, this report, was prepared in order to respond to the comments of EPA, the New Jersey Department of Environmental Protection (NJDEP), Ciba-Geigy Corporation, and the public. In addition, this report incorporates the findings of supplementary investigations conducted by Ciba-Geigy and its consultants.

The purpose of this report is to address the data needs of the Feasibility Study. A site description, a chronology of past remedial actions at the site, and general environmental information are provided in Chapter 2. Chapters 3 through 7 discuss the results of field studies conducted during the Remedial Investigation and conclusions related to the sources of contamination, the extent of on-site and off-site contamination, and the need for mitigation. The Quantitative Baseline Public Health Evaluation contained in Chapter 8 presents conclusions related to impacts on public health and the environment.

2

2.0 BACKGROUND

Section 2.0 provides a description of the site, an overview of site history, past disposal practices, and general information on the demography, land use, and the climatology of the area. Background information on groundwater, soils, surface water, and the biota is presented in Chapters 4.0, 5.0, 6.0, and 7.0, respectively.

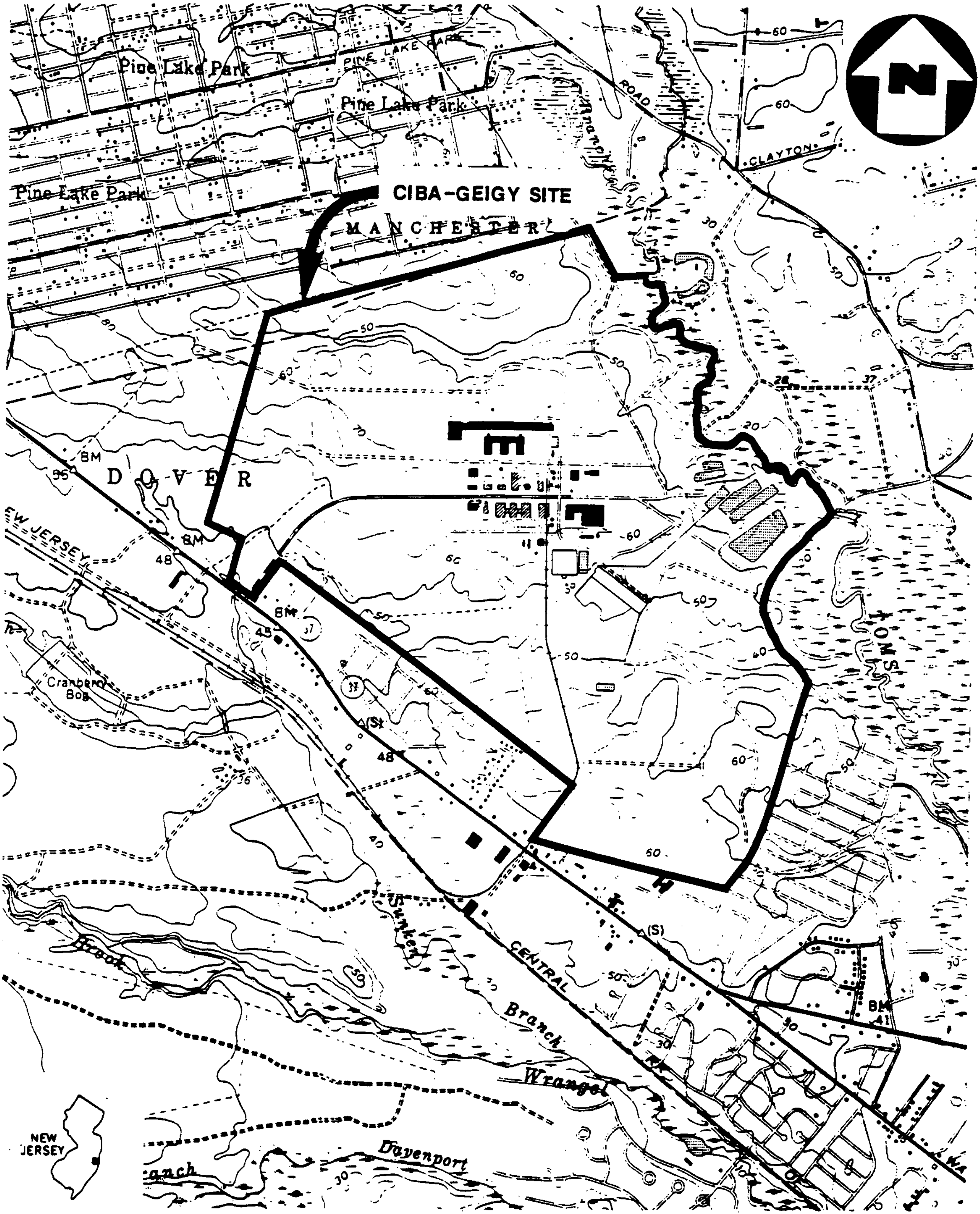
2.1 Site Location and Description

The Ciba-Geigy Site (latitude 39° 59' 19" N, longitude 74° 21' 50" W) is located on Route 37 in Dover Township, Ocean County, New Jersey. Figure 2-1 is the site location map. Three hundred and twenty acres of the 1,275-acre site are developed; the remainder is forested. The manufacturing facilities at Ciba-Geigy are comprised of 30 major buildings, a wastewater treatment plant with a maximum capacity of 9.3 million gallons per day (MGD), and a lined reservoir for emergency storage of untreated and treated wastewater. Figure 2-2 is a site map of the Ciba-Geigy property.

Topographically, the Ciba-Geigy Site is flat but drops off sharply toward the Toms River in the northeastern sector of the property. The Toms River forms the northeastern boundary of the site. Winding River Park, an outdoor recreational area situated on the floodplain of the Toms River, adjoins the site to the east and southeast. The site is bounded on the west by an industrial park, and on the south by residential and commercial properties. Major residential developments, including two planned-retirement communities, are located 1 mile south of the site. The business district of the town of Toms River lies 3 miles southeast of the site.

2.2 Site History

The design of the Remedial Investigation at the Ciba-Geigy Site was largely determined by the processes employed in production at the facility, waste disposal and treatment practices, and prior actions taken to remediate or prevent environmental deterioration at and around the site.



(QUAD) TOMS RIVER, N.J.

SITE LOCATION MAP

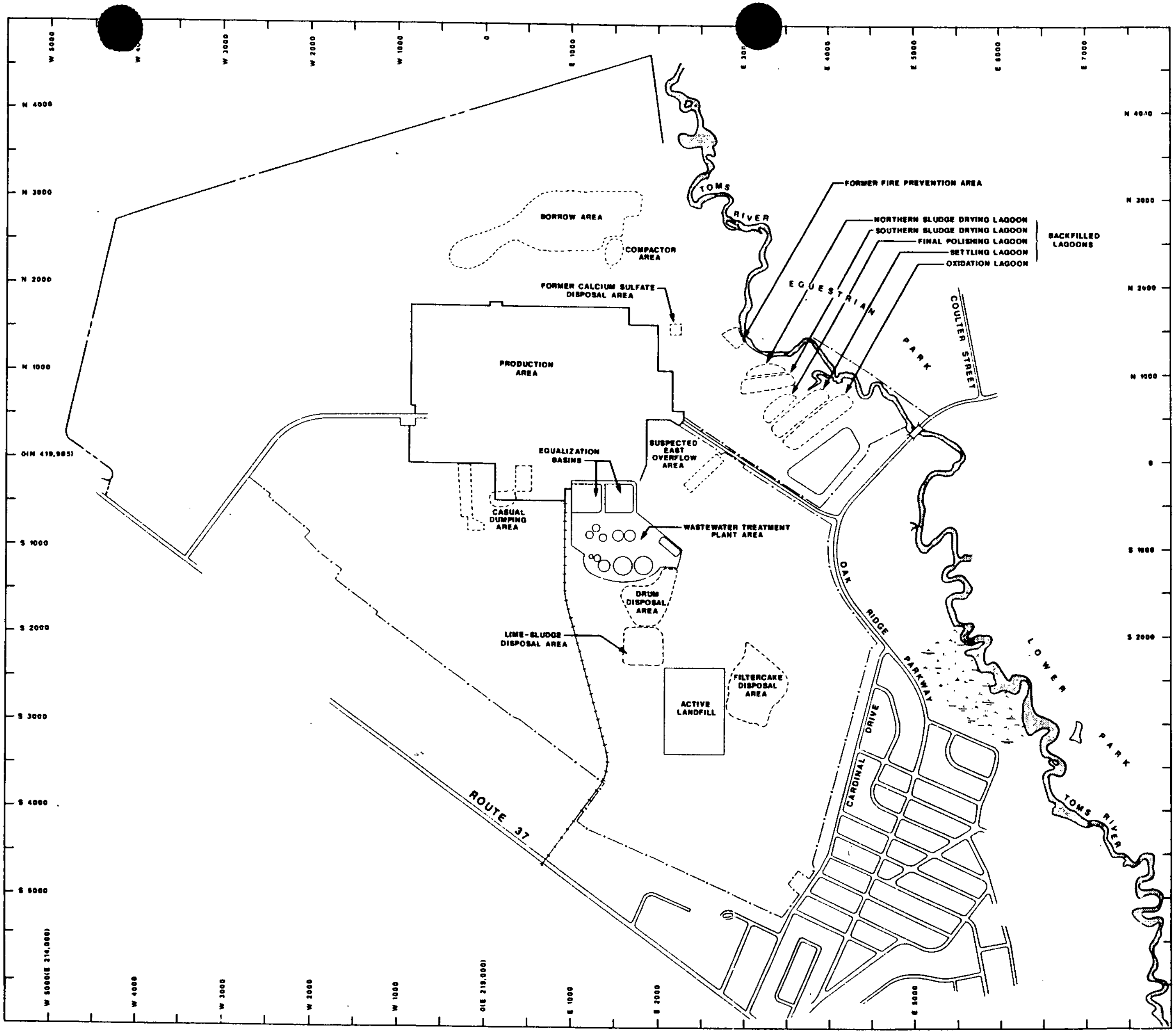
CIBA-GEIGY SITE, DOVER TOWNSHIP, N.J.

SCALE: 1" = 2000'

FIGURE 2-1

NUS CORPORATION

A Halliburton Company



SITE MAP

LEGEND

—+—+—	RAILROAD SPUR
—·—·—	SURVEYED BOUNDARY
—··—··—	BOUNDARY FENCE
-------	BOUNDARY ROAD

FIGURE 2-2

NUS CORPORATION

2.2.1 General Site History

The Toms River Division of Ciba States Limited began construction at the site in 1950 and production in 1952. The firm produced vat dyestuffs and epoxy resins by the Bisphenol A process. By 1960 Toms River Division of Ciba States Limited had merged with Cincinnati Chemical Works, Incorporated, and became the Toms River Chemical Company (TRC). Cincinnati Chemical, owned by the Swiss firms of Ciba Limited, J.R. Geigy, S.A., and Sandoz Limited, produced azo dyestuffs and intermediates. The manufacturing operations of Cincinnati Chemical were moved to the Toms River site; Ciba, Geigy, and Sandoz became co-owners of TRC. In the mid-1970s, Ciba merged with Geigy to become Ciba-Geigy. Sandoz sold its interest within the next few years and in 1981, TRC, a subsidiary of Ciba-Geigy, merged with the Ciba-Geigy Corporation (CAI, 1983).

Ciba-Geigy manufactures a variety of synthetic organic pigments,, organic dyestuffs and intermediates, and epoxy resins. The facility has a daily production capacity of 220,000 pounds of dyestuffs and intermediates, and 105,000 pounds of epoxy resins. Principal markets for these products are the paper and textile industries, and the electronics industry (EPA, 1980).

It has been reported that Ciba-Geigy's future plans for the site include phasing out the current operations and shifting towards pharmaceuticals production.

2.2.2 Past Disposal Practices

Manufacturing processes at Ciba-Geigy generate both liquid and solid wastes. Liquid wastes are treated prior to discharge to the Atlantic Ocean. In the past, solid wastes, consisting of residues from manufacturing processes and sludges from on-site wastewater treatment, were disposed of in bulk or in drums in on-site landfills. At the present time, drummed wastes are being disposed of off site. Wastewater treatment sludge is being stockpiled atop a closed cell of the Active Landfill. A summary of waste products disposed of at the Ciba-Geigy Site is presented in Table 2-1.

TABLE 2-1
SELECTED INVENTORY OF CHEMICALS USED BY CIBA-GEIGY OR DISPOSED OF AS WASTE BY-PRODUCTS
(from CAI, 1983)

Chemical	Raw Material	Active Landfill	Closed Chemical Landfill	Inactive Filtercake Disposal Area	Stack Emissions	Groundwater
<u>Aldehydes and Ketones</u>						
formaldehyde	x					
methyl isobutyl ketone		*			x	
paraformaldehyde	x				x(a)	
<u>Aliphatic Amines</u>						
dimethylamine	x					
monoethylamine	x					
monomethylamine	x					
ethanolamine					x(a)	
<u>Aromatic Amines</u>						
aniline	x	*				
dimethylaniline		*			x	
4,4'-methylenedianiline		*				
toluidines		*				
diphenylamine		*			x(a)	
1,4-phenylene diamine		*				
aniline hydrochloride		*				
3-chloroaniline		*				
4-chloroaniline		*				
2,5-dichloroaniline		*				
xylidine		*				
<u>Benzene Derivatives</u>						
benzene	x	*				
ethylbenzene	x	*				x
toluene	x	*			x	x
resorcinol	x				x	x

x = Present
* = Present, but below the test limit of detectability.
(a) = These air emissions data were taken from NJDEP, Bureau of Air Pollution Control, Air Pollution Enforcement Data System Emissions Report.

TABLE 2-1 (CONT'D)
SELECTED INVENTORY OF CHEMICALS USED BY CIBA-GEIGY OR DISPOSED OF AS WASTE BY-PRODUCTS
(from CAI, 1983)

Chemical	Raw Material	Active Landfill	Closed Chemical Landfill	Inactive Filtercake Disposal Area	Stack Emissions	Groundwater
<u>Chlorinated Benzenes</u>						
chlorobenzene	x	*	x		x	x
1,2-dichlorobenzene		*	x		x	x
1,3-dichlorobenzene						x
1,4-dichlorobenzene						x
1,2,3-trichlorobenzene					x(a)	x
1,2,4-trichlorobenzene		*	x		x	x
chlorotoluene					x(a)	
<u>Chlorinated Aliphatics</u>						
1,2-dichloroethane					x	x
1,1,1-trichloroethane		*				
chloroform						x
trichloroethylene						x
tetrachloroethylene						x
1,2-trans-dichloroethylene						x
<u>Ethers and Epoxides</u>						
anisole		*				
epichlorohydrin					x	
<u>Nitrobenzenes</u>						
nitrobenzene	x	*	x		x	x
2-chloronitrobenzene		*				
4-chloronitrobenzene		*				
<u>Phenolics</u>						
2-chlorophenol		*			x(a)	
2-nitrophenol	x	*				
phenol (phenols)	x	x	x	x	x	x
cresol	x				x(a)	
trichlorophenol	x					

x = Present
* = Present, but below the test limit of detectability.
(a) = These air emissions data were taken from NJDEP, Bureau of Air Pollution Control, Air Pollution Enforcement Data System Emissions Report.

TABLE 2-1 (CONT'D)
SELECTED INVENTORY OF CHEMICALS USED BY CIBA-GEIGY OR DISPOSED OF AS WASTE BY-PRODUCTS
(from CAI, 1983)

Chemical	Raw Material	Active Landfill	Closed Chemical Landfill	Inactive Filtercake Disposal Area	Stack Emissions	Groundwater
<u>Phthalate Esters</u>						
di-n-butylphthalate		*			x	
diethylphthalate		*			x	
<u>Polycyclic Aromatics</u>						
anthracene		*			x	
naphthalene	x	*			x	x
<u>Miscellaneous Organics</u>						
phosgene	x(b)				x	
<u>Inorganics</u>						
arsenic		*	x			x
barium		x				
cadmium		*	x			
chromium		x	x	x		x
copper		x	x	x		x
cyanide		*				
iron		x	x	x		x
lead		x	x			x
manganese			x			
mercury		x	x		x	x
nickel		x				
selenium		x				
silver		*				
zinc		x	x		x	x

x = Present

* = Present, but below the test limit of detectability.

(a) = These air emissions data were taken from NJDEP, Bureau of Air Pollution Control, Air Pollution Enforcement Data System Emissions Report.

(b) = Phosgene is no longer used by Ciba-Geigy.

Known past or present disposal areas for chemical wastes at Ciba-Geigy include:

- Backfilled Lagoons
- Drum Disposal Area
- Lime Sludge Disposal Area
- Filtercake Disposal Area
- Wastewater Treatment Plant Area
- Active Landfill
- Former Calcium Sulfate Disposal Area

As known disposal areas they represent known or suspected sources of contaminant release at Ciba-Geigy. In addition, the following facility areas have been identified as possible past disposal areas:

- Production Area
- Compactor Area
- Former Fire Prevention Training Area
- Borrow Area
- Suspected East Overflow Area
- Casual Dumping Area

These areas as well as the known disposal areas represent potential sources of contaminant release at Ciba-Geigy. The locations of these source areas are depicted in Figure 2-2. Further discussion and characterization of each source area are provided in Chapter 3.0.

2.2.3 Past Response Actions

Various response actions have been taken at the Ciba-Geigy Site during the period 1976 to 1987 to remediate or prevent environmental deterioration. These include closure activities of disposal areas, administrative orders, environmental investigation programs, and the submittal of investigative reports. A chronology of these actions is provided in Appendix B.

2.3 Environmental Setting

Social and environmental factors including demography, land use, and climatology were used to evaluate contaminant migration routes. The following is a summary of these factors.

2.3.1 Climate

Monthly climatological data for temperature and precipitation at Freehold, New Jersey and precipitation data at the Ciba-Geigy Site are presented in Table 2-2. The Freehold meteorological station is located in Monmouth County, 20 miles north of the Ciba-Geigy Site. These data are based on records of the 30-year period 1951-1980 inclusive. A 30-year time period is routinely employed to compute climatological norms.

Large-scale weather patterns normally move eastward across New Jersey. The proximity of the Ciba-Geigy Site to the Atlantic Ocean, however, results in localized modifications to the regional temperature, wind, and rainfall patterns due to the differential heating and cooling of the land and sea.

Precipitation totals generally are well distributed throughout the year. However, year-to-year variations recorded in late summer and early autumn may result from the northward passage of tropical storms. In years that these seasonal storms occur, annual precipitation totals tend to be higher than normal. As shown, Toms River typically registers its highest average monthly precipitation total in August (4.98 inches) and its lowest in June (3.41 inches).

2.3.2 Demography and Land Use

Dover Township had a 1980 Census population of 64,455 residents, with a majority of the population residing east of the Garden State Parkway. Single-family residential neighborhoods to the south and east of the Ciba-Geigy Site have populations of 900 and 1,800, respectively. A planned-retirement community is located 3 miles north of the site, and a residential development of 180 units is

TABLE 2-2
AVERAGE MONTHLY TEMPERATURE AND PRECIPITATION
FREEHOLD, NEW JERSEY
(1951-1980)

Month	Temperature (°F)	Precipitation (in)	Precipitation (in) at Ciba-Geigy Site*
January	30.5	3.55	3.55
February	32.0	3.28	3.42
March	40.1	4.44	4.28
April	50.8	3.66	3.95
May	60.6	3.75	3.61
June	69.5	3.47	3.41
July	74.2	4.04	4.65
August	72.9	4.64	4.98
September	66.2	3.67	3.78
October	55.4	3.52	3.91
November	45.4	3.96	3.92
December	34.6	3.91	4.22
Annual	52.7 (Avg.)	45.89 (Total)	47.68 (Total)

*Average monthly precipitation at Toms Rivers, New Jersey.

SOURCE: National Oceanic and Atmospheric Administration (NOAA), 1982.

located less than one-half mile north of the site across the Toms River. Manchester Township to the west of the Ciba-Geigy Site had a population in 1980 of 27,987. A large single-family residential development of 4,500 people, Pine Lake Park, lies within 1 mile to the northwest of the site. In 1980, the census population of Berkeley Township, south of the Ciba-Geigy Site, was 23,151, with a majority of the population residing in developments west of the Garden State Parkway and 1 mile south of the site. Two planned-retirement communities, Silver Ridge and Holiday City, are located within these residential areas and have populations totalling 9,000.

The Ciba-Geigy Site is located in an area of residential development, recreational areas, small commercial establishments, and light industrial complexes (Fig. 2-1). Commercial areas are located southwest of the site along Route 37. The area west of Ciba-Geigy is zoned for industrial use, including light manufacturing and warehouse operations. Residential areas of Dover Township are supplied with municipal water from the Toms River Water Company, which maintains 20 supply wells both to the northeast and southeast of Ciba-Geigy. The residents of the Pine Lake Park area of Manchester Township are supplied by private residential wells. There are various other residences that are still using private wells for domestic use in the Coulter Street and Cardinal Drive communities.

3

3.0 WASTE CHARACTERIZATION STUDIES

The objectives of the waste characterization studies are to: (1) identify potential source areas on site, (2) review information and data available on each source area, (3) determine likely hazardous substances present, (4) estimate waste volumes, (5) determine physical state of hazardous substances, and (6) determine the possibility of further action based on regulatory guidelines and data requirements.

3.1 Introduction

As initially presented in Section 2.2.2, the following are known disposal areas for wastes at the Ciba-Geigy chemical plant in Toms River:

- Backfilled Lagoons
- Drum Disposal Area
- Lime Sludge Disposal Area
- Filtercake Disposal Area
- Wastewater Treatment Plant Area
- Active Landfill
- Former Calcium Sulfate Disposal Area

In addition to the known disposal areas, the following areas at Ciba-Geigy have also been identified as potential repositories of past- or presently-generated waste:

- Production Area
- Compactor Area
- Former Fire Prevention Training Area
- Borrow Area
- Suspected East Overflow Area
- Casual Dumping Area

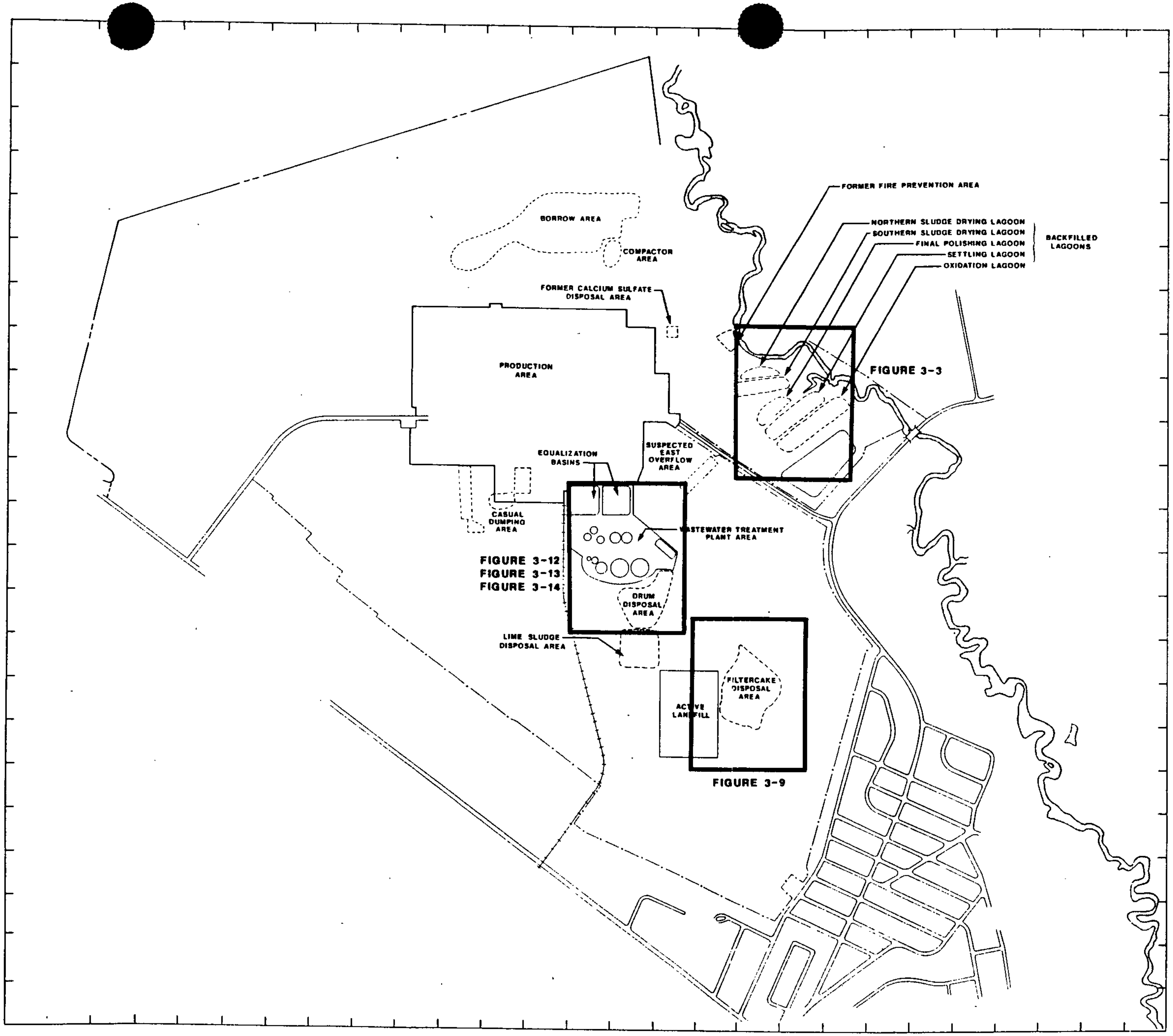
These areas, as well as the known disposal areas, represent potential sources of contaminant release at Ciba-Geigy. The following discussions provide information on each potential source area. Figure 3-1 shows the location of these areas at the Ciba-Geigy Site along with reference locations for subsequent figures in this section, and Figure 3-2 shows the location of monitoring wells used in evaluating the impact of each source area on groundwater.

3.2 Informational Sources

Waste characterization began with a compilation of records generated by Ciba-Geigy and public agencies. In addition, EPA provided NUS with a series of photographs which documented the course of the firm's waste disposal practices.

To further define these potential sources, NUS retained the services of Weston Geophysical who completed Ground Penetrating Radar (GPR) surveys in potential source areas. A report of the geophysical services and results as interpreted by Weston Geophysical appears in Appendix D-1. Each of the six locations surveyed contained at least one potential source area to be profiled by GPR. Each location was profiled by at least two GPR transects to provide size limits to the suspected source area and physical characteristics to the waste (i.e, bulk, drummed, etc.). It was important to determine the size and characteristics of the wastes sites in order to minimize the hazards of drilling and sampling through unstable wastes. Figures 3 through 8 of Appendix D-1 show the locations of the GPR surveys within each of the six source areas.

Based on results of the radar survey, eight sampling locations were selected, and the drilling phase of the waste characterization program began on September 4, 1985. At each selected sampling location, a decontaminated 6-inch hollow-stem auger was advanced to a depth of 2 feet, and a decontaminated split-barrel sampler was lowered through the auger and driven an additional 2 feet into undisturbed material at the bottom of the borehole by using a 140-pound

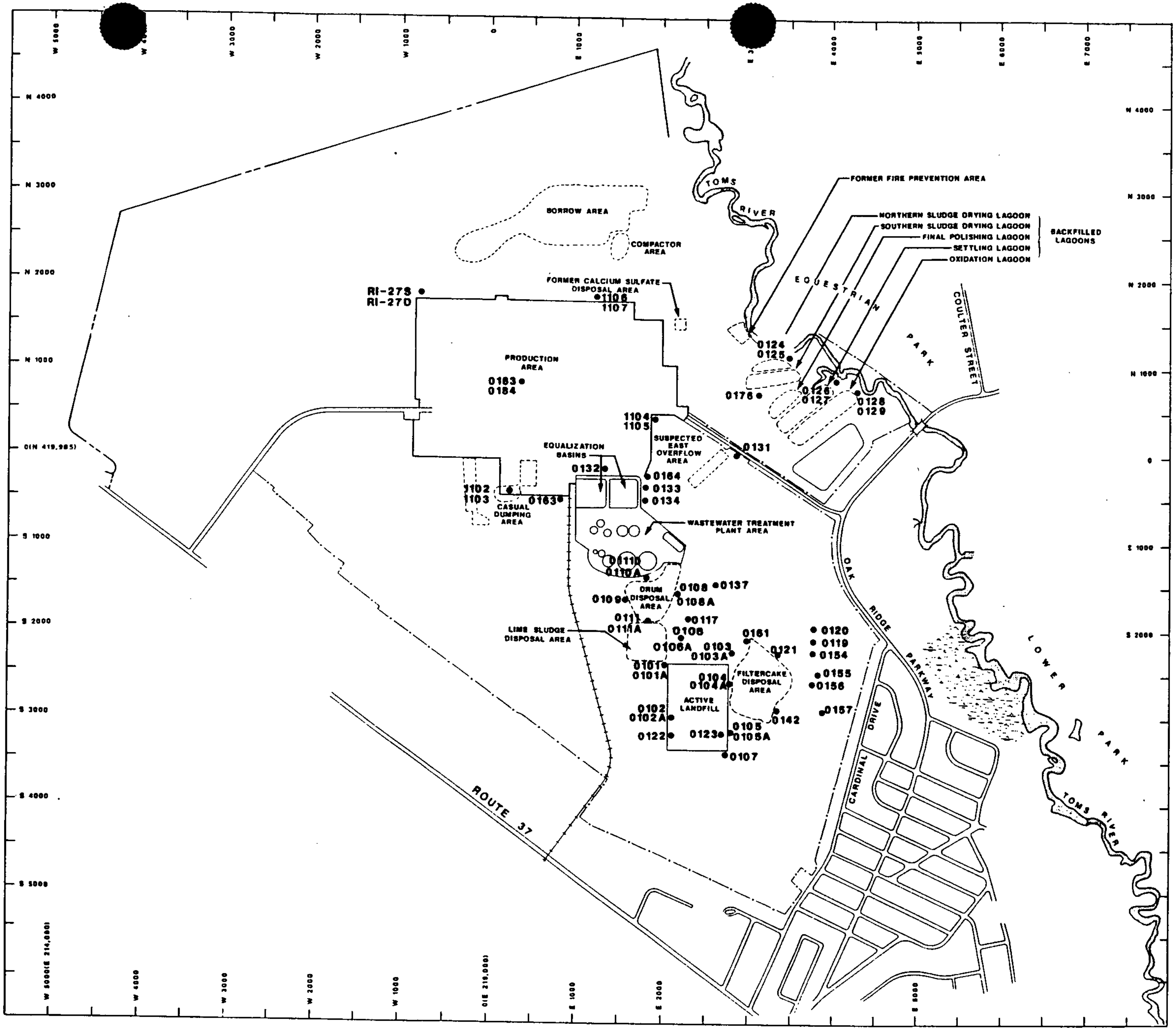


SUSPECTED CONTAMINANT SOURCE AREAS WITH THE LOCATION OF SUBSEQUENT SECTION FIGURES IDENTIFIED CIBA-GEIGY, TOMS RIVER, N.J.

APPROXIMATE SCALE - 1"= 900'

FIGURE 3-1

NUS CORPORATION



LOCATIONS OF SELECTED WELLS IDENTIFIED IN SUBSEQUENT TABLES

LEGEND

- RAILROAD SPUR
- SURVEYED BOUNDARY
- BOUNDARY FENCE
- BOUNDARY ROAD

FIGURE 3-2

NUS CORPORATION

hammer. Blow counts were recorded, the sampling device was recovered from the hole, and the retrieved material was monitored for emissions, described, and secured in appropriately identified containers. The augers were then advanced through the sampled interval to a depth indicated by the NUS geologist-in-charge. The sampling procedure was repeated in this manner until either the water table or a recognizable geologic stratum was encountered. Upon completion of sampling, the borehole was tremie-grouted to grade and flagged for surveying.

Four samples from each borehole were selected for laboratory analysis. A representative portion of each was submitted for determination of Hazardous Substance List (HSL) parameters, and a composite sample representing the four selected intervals was submitted for dioxin analysis.

Laboratory analytical data generated by the waste characterization program are included in the Appendix A. Methylene chloride, acetone, and 2-butanone were detected in most samples in concentrations as high as several thousand ppb, but because these same compounds were detected in several laboratory blanks, they are considered as having been introduced to the samples either in the field or in the laboratory. Accordingly, these compounds are given no further consideration under this heading. Pesticides analyses for all samples from boreholes RI-A-3 through RI-A-8 failed to meet QA/QC requirements, as did semivolatiles analyses for all samples taken from boreholes RI-A-6 through RI-A-8.

Additional studies performed by Ciba-Geigy's consultant, AWARE Incorporated, were also used to evaluate the Backfilled Lagoons Area, Filtercake Disposal Area, and the Wastewater Treatment Plant Area.

3.3 Source Area Review

Within this section is the review of each source area based on the above-outlined informational sources. Each source area was evaluated and a conclusion drawn as to whether regulatory constraints and data availability would allow further remedial action review.

3.3.1 Backfilled Lagoons

The Backfilled Lagoons Area contains five separate unlined lagoons and is located due east of the plant production area. These lagoons are from 400 to 600 feet west of the Toms River, and they border the 100-year floodplain (Floodplain Map, Dover Township, 1983). The lagoons roughly parallel each other along a north-to-south line along the river. These lagoons were part of the old wastewater treatment system which was in operation from 1952 to 1977. When the lagoons were in operation, they received the effluent from the primary wastewater treatment system which was located at the site of the current wastewater treatment plant. The three southern lagoons were connected in series and were used for secondary water treatment. The first of these was the settling lagoon located in the middle of the three southern lagoons. The second lagoon, located just south of the settling lagoon, was the oxidation basin which was utilized for biological treatment. The third lagoon, located just north of the settling lagoon, was the final polishing pond for treated wastewater before being discharged to receiving waters. The two northernmost lagoons were utilized as sludge drying beds (U.S. EPA, 1976). Closure operations were completed in 1978 and involved the removal of any waste which could be pumped and then backfilling the lagoons to grade with soil and sand. During the years of operation dried sludge removed from the lagoons was disposed of in the Filtercake Disposal Area. On closure, sludge which could be removed by pumping was dewatered and placed in the active landfill. NUS Corporation Region 2 FIT completed a boring in each of the five lagoons as part of its investigation in 1985. In addition, AWARE completed four borings in 1985 (AWARE, 1986) and several additional borings as part of a detailed investigation in 1987 (AWARE 1987a). Figure 3-3 shows the boring locations, and Table 3-1 shows the NUS estimates of sludge volume based on its borings.

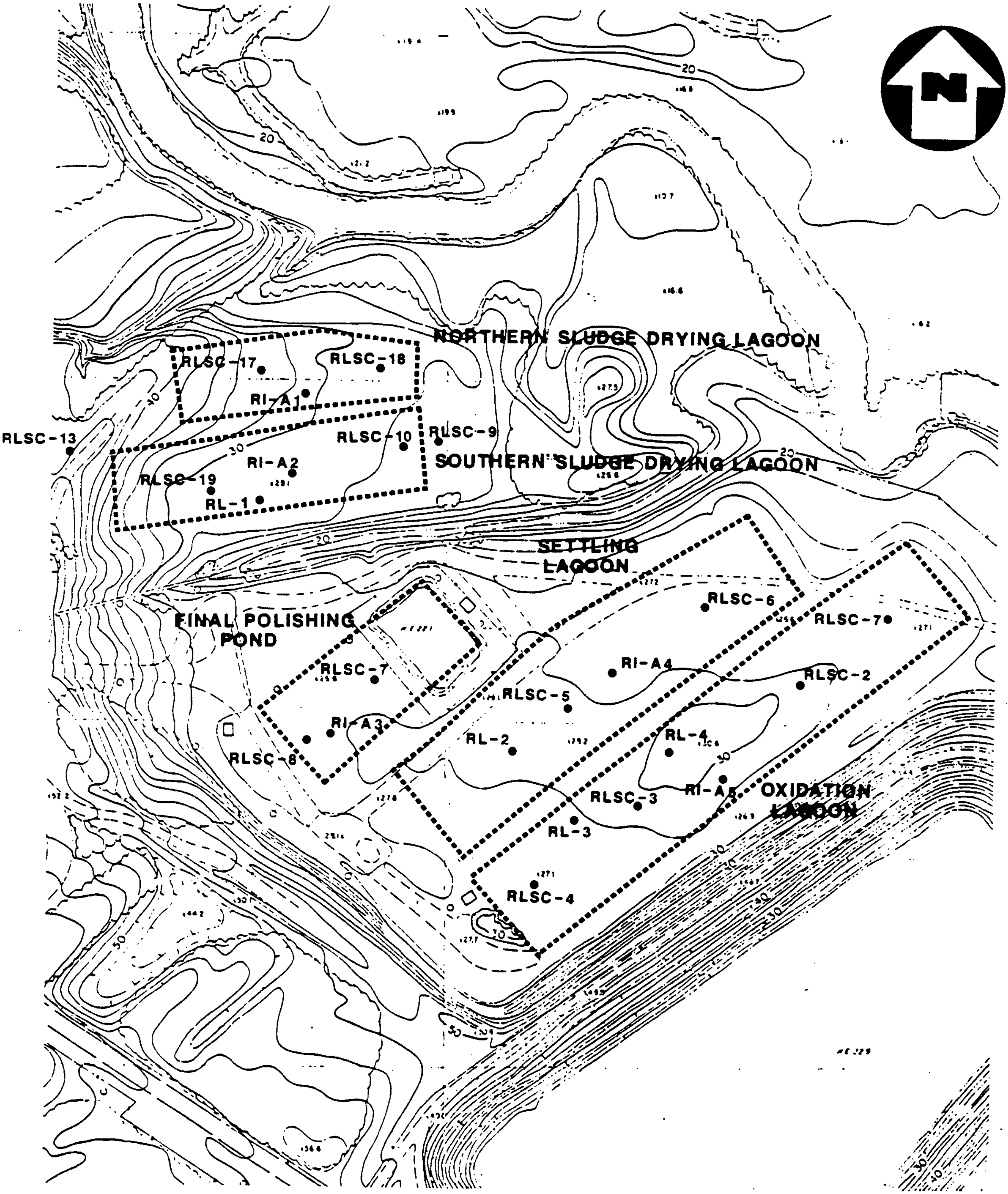


FIGURE 3-3

BACKFILLED LAGOONS AREA
BORING LOCATIONS
CIBA-GEIGY, TOMS RIVER, N.J.

NUS CORPORATION

APPROXIMATE SCALE - 1"=200'

TABLE 3-1
DIMENSIONS AND VOLUMES OF SLUDGE AND CONTAMINATED MEDIA IN THE BACKFILLED LAGOONS

Lagoon	Area (acres)	Thickness (ft)	Volume (yd^3)	% Sludge	Volume Sludge (yd^3)
Northern Sludge Drying Lagoon	0.81	15	19,500	33	6,640
Southern Sludge Drying Lagoon	1.3	16	32,700	28	9,160
Polishing Pond	0.71	17	19,500	3-5	780
Settling Lagoon	2.8	12	54,300	4-5	2,450
Oxidation Basin	2.9	17	80,600	15	12,100

Note:
Conclusions based on NUS boring logs and Ground Penetrating Radar Surveys (Weston Geophysical, 1985)

Northern Sludge Drying Lagoon

The first of the two sludge drying lagoons, the northernmost lagoon, covers an area of 0.81 acre. At the time of closure the lagoon bottom elevation was recorded at +21 Mean Sea Level (MSL) (Cesareo and Morales, 1980). Auger boring RI-A1 completed by NUS Corporation Region 2 FIT (Figure 3-4) revealed the beginnings of a sludge layer at +21.5 MSL, and in all, encountered four separate sludge layers between the elevations of +21.5 to +13.2 MSL. The auger boring indicates that a large quantity of sludge remained after backfilling. This conclusion is attributed to the fact that a sludge drying bed would contain a high volume of dewatered sludge which cannot be pumped. Rough calculations based on the auger boring suggests a total sludge volume of 6,640 yd^3. Figure 3-3 provides the locations of this and other auger borings conducted by NUS. AWARE has recently completed two additional borings (RLSC-17, RLSC-18) in this lagoon (AWARE, September 1987).

Southern Sludge Drying Lagoon

The second sludge drying lagoon was 1.3 acres in size. On closure the lagoon had a recorded bottom elevation of +21 MSL (Cesareo and Morales, 1980). Auger boring RI-A2 by NUS (Figure 3-5) revealed a sludge layer at +23.1 MSL and, like the first sludge drying lagoon, revealed four distinct sludge layers between the elevations of +23.1 MSL and +15.5 MSL. Calculations based on the NUS auger borings estimate that the total volume of sludge remaining is 9,160 yd^3. AWARE Corporation boring RL-1 (AWARE,1986) was completed shortly after RI-A1 was drilled. AWARE also completed borings RLSC-9, RLSC-10, and RLSC-19 (AWARE, September 1987) in 1987.

NUS CORPORATION

TDD NO. 02-8408-04B	DATE: START 9/4/85 FINISH 9/5/85
PROJECT NAME Toms River Chemical Co	ELEVATIONS Above Mean Sea Level
LOCATION RI-A-1	GROUND SURFACE +28.2
DIAMETER: CASING ID N/A	GROUND WATER
ROCK CORE N/A	DEPTH OF HOLE 16.0'
COORDINATES: NORTH 0995	OVERBURDEN N.A. ROCK N.A.
EAST 3311	DIP N.A.
CONTRACTOR A.C. Schultes & Sons Inc LOGGED BY J. Grelis	CHECKED BY R. TEIFKE
DRILLING METHOD Hollow Stem Auger	SHEET 1 OF 1

GEOLOGIC PROFILE

DEPTH (FT.)	ELEV. (FT.)	SYMBOL	SAMPLE TYPE AND No.	SAMPLE BLOWS OR REC.	SAMPLE DEPTH RANGE (FT.)	RQD %
			SS-1	11-5-3-2	2-4	0.85
5			SS-2	14-3-2-1	4-6	0.75
			SS-3 BW 1	5-3-2-2	6-8	2.00
			SS-4	0-1-19-35	8-10	2.00
10			SS-5 BW 2	14-44-36-26	10-12	2.00
			SS-6 BW 3	14-15-18-29	12-14	1.40
15			SS-7 BW 4	18-13-21-21	14-16	1.80

ANALYTICAL RESULTS

BW 1

Chlorobenzene	2100	Cr	1019
Toluene	74100	Cu	1168
Ethylbenzene	19000	Pb	195
Xylenes	49000	Hg	17
2-Hexanone	3100	Va	210
4--Methyl-2-Pentanone	2800		

BW 2

Chlorobenzene	26	Cr	17
Toluene	510	Pb	21
Ethylbenzene	68		
Xylenes	290		
4-Methyl-2-Pentanone	5		
1,2-Dichloropropane	9		

BW 3

Cr	9.1
Pb	4.3
Hg	0.45

BW 4

Toluene	12000	Cr	435
Ethylbenzene	2300	Cu	553
Xylenes	2900	Pb	97
2-Hexanone	1100	Hg	1.7
4-Methyl-2-Pentanone	1800	Va	93

SYMBOLS

■	SLUDGE
░	SAND/GRAVEL
▒	STAINED SAND
▩	CLAY

ANALYTICAL RESULTS

ORGANICS IN ug/kg
INORGANICS IN mg/kg

FIGURE 3-4

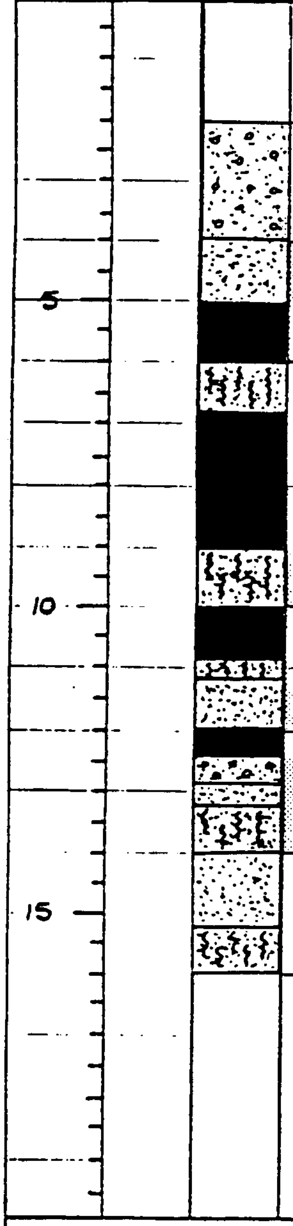
BOREHOLE LOG AND CHEMICAL ANALYSES

NUS CORPORATION

TDD NO. 02-8408-04B
PROJECT NAME Toms River Chemical Co
LOCATION RI-A-2
DIAMETER : CASING ID N/A
ROCK CORE N/A
COORDINATES: NORTH 0861
EAST 3233
CONTRACTOR A.C. Schultes & Sons Inc. LOGGED BY J. Grelis
DRILLING METHOD Hollow Stem Auger

DATE: START 9/5/85 FINISH 9/6/85
ELEVATIONS Above Mean Sea Level
GROUND SURFACE +28.1
GROUND WATER
DEPTH OF HOLE 16.0'
OVERBURDEN N.A. ROCK N.A.
DIP N.A.
CHECKED BY R. TEIFKE
SHEET 1 OF 1

GEOLOGIC PROFILE



SAMPLE TYPE AND No.	SAMPLE BLOWS OR REC.	SAMPLE DEPTH RANGE (FT.)	ROD %
SS-1	19-3-3-2	2-4	1.25
~~SS-2~~ BW 5	5-0-1-0	~~4-6~~	~~1.50~~
SS-3	2-2-16-43	6-8	2.00
SS-4 BW 6	14-27-38-41	8-10	2.00
SS-5 BW 7	25-21-15-15	10-12	2.00
SS-6 BW 8	13-9-13-19	12-14	2.00
SS-7	23-12-14-25	14-16	2.00

ANALYTICAL RESULTS

BW 5

Toluene	890	Cr	343
Xylenes	1100	Cu	723
		Pb	59
		Hg	1.2
		As	8

BW 6

Chlorobenzene	2100	Cr	443
Toluene	14000	Cu	3629
Ethylbenzene	19000	Pb	314
Xylenes	55000	Hg	31
Phenanthrene	79000	As	161

BW 7

Toluene	3800	Cr	490
Ethylbenzene	5600	Cu	1488
Xylenes	26000	Pb	120
1,2,4-Trichlorobenze	46000	Hg	18
Phenanthrene	42000	As	101

BW 8

Toluene	7.4	Cr	651
Ethylbenzene	31	Cu	730
Xylenes	30	Pb	120
		Hg	12
		As	19
		Va	90

SYMBOLS

■	SLUDGE
⁘	SAND/GRAVEL
▒	STAINED SAND
▨	CLAY

ANALYTICAL RESULTS

ORGANICS IN ug/kg
INORGANICS IN mg/kg

FIGURE 3-5

BOREHOLE LOG AND CHEMICAL ANALYSES

Settling Lagoon

The former settling lagoon covers 2.8 acres (NUS, 1986) and had a recorded bottom elevation of +20.5 MSL (Cesareo and Morales, 1980). Auger boring RI-A-4 (Figure 3-6) completed by NUS revealed a thin sludge layer (0.5 foot) at +22.5 MSL and stained sands at +17 MSL. AWARE auger boring RL-2 (AWARE, 1986) did not encounter any sludge layer but did reveal stained sands. Two additional borings by AWARE RLSC-5, RLSC-6 (AWARE, September 1987) encountered sludge layers 2.5 feet thick. A third boring, RLSC-12, was outside the lagoon confines. By nature, a settling lagoon requires a large detention time (i.e., large volume) in order to allow sufficient time for coagulants to settle. As a result, any remaining sludge would be spread over the large lagoon bottom as compared to the more compact area of a sludge drying bed. Therefore, sludge volumes are difficult to predict. However, an estimate of 2,450 yd^3 was made by NUS based on its soil boring. Also, like the polishing pond, the settling lagoon shows the possible presence of drums in the western half of the lagoon according to a Ground Penetrating Radar survey (Weston Geophysical, 1985).

Oxidation Basin

The former oxidation basin covers an area of 2.9 acres (NUS, 1986). On closure this lagoon had a bottom elevation of +20.5 MSL (Cesareo and Morales, 1980). Seven borings are available for this lagoon: RI-A-5 completed by NUS Corporation Region 2 FIT (Figure 3-7) and RL-3, RL-4, RLSC-1, RLSC-2, RLSC-3, and RLSC-4 completed by AWARE (AWARE, 1986, 1987a). RI-A-5 records a sludge layer between +19 MSL and +13 MSL. The NUS boring also records a stained sand layer at +23 MSL. When the NUS boring is compared with the AWARE borings, however, a wide fluctuation in sludge layer thicknesses and sludge layer volumes is evident. Therefore, only a rough estimate of sludge volume can be made. Based on the results of the NUS auger boring, the sludge volume is estimated at 12,100 yd^3.

NUS CORPORATION

TDD NO. 02-8408-04 B
PROJECT NAME Toms River Chemical Co.
LOCATION RI-A-4
DIAMETER: CASING ID N/A
ROCK CORE N/A
COORDINATES: NORTH 0569
EAST 3720
CONTRACTOR A.C. Schultes & Sons., Inc. LOGGED BY J. Grelis
DRILLING METHOD Hollow Stem Auger

DATE: START 9/11/85 FINISH 9/12/85
ELEVATIONS ABOVE MEAN SEA LEVEL
GROUND SURFACE + 27.8
GROUND WATER
DEPTH OF HOLE 18.0'
OVERBURDEN N.A. ROCK N.A.
DIP N.A.
CHECKED BY R. TEIFKE
SHEET 1 OF 1

GEOLOGIC PROFILE

DEPTH (FT.)	ELEV. (FT.)	SYMBOL	SAMPLE TYPE AND No.	SAMPLE BLOWS OR REC.	SAMPLE DEPTH RANGE (FT.)	ROD %	ANALYTICAL RESULTS
							BW 14
		░	SS-1	11-10- 10-10	2-4	1.60	Pb 3.1 Hg 0.12
5		■ ░	SS-2	12-8- 5-4	4-6	1.20	BW 15 Toluene 1800 Cr 13 Hg 0.24
		░ ▒	SS-3	7-15- 36-46	6-8	2.00	BW 16 Cr 12 Pb 6.9 Hg 0.31
		░ ░	SS-4 BW 14	26-35- 38-43	8-10	2.00	
10		░ ▒	SS-5 BW 15	23-32- 30-25	10-12	2.00	BW 17 Cr 7.3 Hg 0.29
		░ ░ ░	SS-6 BW 16	10-12- 16-14	12-14	2.00	
15		░	SS-7 BW 17	7-7- 11-18	14-16	2.00	
		░	SS-8	8-15- 20-19	16-18	2.00	

SYMBOLS

■ SLUDGE
░ SAND/GRAVEL
▒ STAINED SAND
▩ CLAY

ANALYTICAL RESULTS

ORGANICS IN ug/kg
INORGANICS IN mg/kg

FIGURE 3-6

BOREHOLE LOG AND CHEMICAL ANALYSES

NUS CORPORATION

TDD NO. 02-8408-04B	DATE: START 9/12/85 FINISH 9/13/85
PROJECT NAME Toms River Chemical Co.	ELEVATIONS Above Mean Sea Level
LOCATION RI-A-5	GROUND SURFACE +28.9
DIAMETER: CASING ID N/A	GROUND WATER
ROCK CORE N/A	DEPTH OF HOLE 18.0'
COORDINATES: NORTH 0366	OVERBURDEN N.A. ROCK N.A.
EAST 3745	DIP N.A.
CONTRACTOR A.C. Schultes & Sons, Inc LOGGED BY J. Grelis	CHECKED BY R. Teifke
DRILLING METHOD Hollow Stem Auger	SHEET 1 OF 1

GEOLOGIC PROFILE

DEPTH (FT.)	ELEV. (FT.)	SYMBOL	SAMPLE TYPE AND No.	SAMPLE BLOWS OR REC.	SAMPLE DEPTH RANGE (FT.)	ROD %
		▨	SS-1	3-2-3-4	2-4	1.10
5		▨	SS-2	5-2-4-2	4-6	1.30
		▨	SS-3	2-5-3-4	6-8	1.25
10		▨	SS-4 BW 18	0-1-1-1	8-10	1.70
		■	SS-5 BW 19	1-2-16-29	10-12	2.00
		*			12-14	
15		■	SS-6 BW 20	15-25-14-15	14-16	2.00
		▨	SS-7 BW 21	5-12-25-35	16-18	2.00

ANALYTICAL RESULTS (ppb)

BW 18

		Cr	100
		Cu	150
		Pb	6.6
		Hg	0.59

BW 19

Toluene	4300	Cr	71
Xylenes	4200	Cu	83
2,4,6-Trichlorophenol	3800	Pb	12
		Hg	0.47

BW 20

Toluene	1500	Cr	327
		Cu	348
		Pb	19
		Hg	1.9
		Va	38

BW 21

		Cr	114
		Cu	316
		Pb	30
		Hg	9.7
		Va	36

SYMBOLS

■	SLUDGE
⁘	SAND/GRAVEL
≀	STAINED SAND
▩	CLAY

ANALYTICAL RESULTS

ORGANICS IN ug/kg
INORGANICS IN mg/kg

FIGURE 3-7

BOREHOLE LOG AND CHEMICAL ANALYSES

Polishing Pond

The wastewater treatment plant's final polishing pond is currently divided into two parts. Until 1987 when the lagoon was closed, the eastern half of this lagoon contained a lined lagoon for the current wastewater treatment plant ocean outfall pump (CAI, 1983). The remaining area of the lagoon, which has been backfilled, covers an area of 0.71 acre and had a recorded depth of +16 MSL (Cesareo and Morales, 1980) at closure. The NUS auger boring RI-A-3 (Figure 3-8) found a thin sludge layer at +21.6 MSL. Two recent AWARE borings, RLSC-7 and RLSC-8 (AWARE, September 1987), encountered thin sludge layers (less than 6 inches wide) within this lagoon. A conservative estimate based on the NUS boring gives a sludge volume of 780 yd^3. Because this lagoon received the wastewater after settling and biological treatment, it is expected to have the lowest quantity of sludge. Visibly stained soil, however, did extend to a depth of +10 MSL. Also of note is the potential presence of drums near the southwestern edge of the lagoon as indicated by a ground penetrating radar survey (Weston Geophysical, 1986).

Data Summary and Conclusions

During the boring process, samples of sludge and soils were obtained by NUS in 1985. Data from these borings are outlined in Table 3-2. Data for the Filtercake Area borings are also included in Table 3-2, but will be discussed in Section 3.3.4. From these data it is readily apparent that the Northern and Southern Sludge Drying Lagoons contain a greater concentration of organics than any of the process lagoons. In addition, with the exception of the Polishing Pond, organics are contained in the sludge. Inorganic contamination was detected in all of the lagoons. The extensive AWARE boring program in 1987 found the same compounds as those detected by NUS. In addition, AWARE also detected significant levels of base/neutral organic compounds including dichlorobenzenes, hexachlorobenzene, various polycyclic aromatic hydrocarbons and their substituted derivatives, and trichlorinated phenols (AWARE, 1987a). As with the NUS analysis, the predominance of the contamination was located within the former sludge drying lagoons.

NUS CORPORATION

TDD NO. 02-8408-04B	DATE: START 9/11/85 FINISH 9/11/85
PROJECT NAME Tom River Chemical Co.	ELEVATIONS Above Mean Sea Level
LOCATION RI-A-3	GROUND SURFACE +27.6
DIAMETER: CASING ID N/A	GROUND WATER
ROCK CORE N/A	DEPTH OF HOLE 18.0'
COORDINATES: NORTH 0487	OVERBURDEN N.A. ROCK N.A.
EAST 3338	DIP N.A.
CONTRACTOR A.C. Schultes & Sons, Inc. LOGGED BY J. Grelis	CHECKED BY R. TEIFKE
DRILLING METHOD Hollow Stem Auger	SHEET 1 OF 1

GEOLOGIC PROFILE

DEPTH (FT)	ELEV. (FT.)	SYMBOL	SAMPLE TYPE AND No.	SAMPLE BLOWS OR REC.	SAMPLE DEPTH RANGE (FT)	ROD %
			SS-1	25-9-4-4	2-4	1.40
5			SS-2 BW 10	10-4-3-22	4-6	1.50
			SS-3 BW 11	5-1-3-17	6-8	1.50
			SS-4	6-4-19-18	8-10	1.75
10			SS-5	6-7-10-13	10-12	2.00
			SS-6 BW 12	17-10-15-25	12-14	2.00
15			SS-7	17-15-15-11	14-16	1.80
			SS-8 BW 13	9-9-12-13	16-18	2.00

ANALYTICAL RESULTS

BW 10

Cr	16
Pb	21
Hg	0.31

BW 11

Cr	20
Pb	4.5
Hg	0.61

BW 12

Cr	25
Pb	4.4
Hg	2.2
Cd	21

BW 13

Cr	61
Pb	13
Hg	1.3
Cu	67

SYMBOLS

■	SLUDGE
⁘	SAND/GRAVEL
≀	STAINED SAND
▨	CLAY

ANALYTICAL RESULTS

ORGANICS IN ug/kg
INORGANICS IN mg/kg

FIGURE 3-8

BOREHOLE LOG AND CHEMICAL ANALYSES

TABLE 3-2
MAXIMUM CONCENTRATIONS OF CONTAMINANTS FOUND IN LAGOON AND FILTERCAKE AREA SLUDGE BORING SAMPLES
(ORGANICS IN ppb AND METALS IN ppm)

Contaminant	Northern Sludge Drying Lagoon	Southern Sludge Drying Lagoon	Polishing Pond	Settling Lagoon	Oxidation Basin	Filtercake Area
Chlorobenzene(a) (b)	2100	2100				
Toluene(a) (b)	24100	14000		1800	4300	5400
Ethylbenzene(a) (b)	19000	19000				
Xylenes	40000	55000			4200	990
2-Hexanone	11000					470
4-Methyl-2-pentanone	1800					330
1,2-Dichloropropane	9					
Phenanthrene		42000				
1,2,4-Trichlorobenzene(b)		46000				
2,4,6-Trichlorophenol					3800	
Tetrachloroethene(b)						2100
1,1,2,2-Tetrachloroethane						50
Arsenic		160				
Cadmium			21			
Chromium	1019	651	61	13(c)	327(d)	1659(d)
Copper	1168	3629	67(c)		348(d)	2433(d)
Lead	195	314	21	3.1	30(d)	321(d)
Mercury	17	31	3.2		9.7(d)	64(d)
Nickel						26
Vanadium				0.29		120(d)
Zinc						291(d)

(a) = Also found in wells downgradient of lagoons.

(b) = Also found in wells downgradient of Filtercake Area.

(c) = Found in stained sand layers only.

(d) = Found in stained sand layers as well as sludge.

A review of groundwater monitoring data from the lagoon area is outlined in Table 3-3. From these data it is apparent that contamination of groundwater exists in the Backfilled Lagoons Area. In addition, the electromagnetic survey completed by U.S. EPA contractors shows an area of higher conductivity underlying the sludge drying lagoons. However, contaminants cannot be readily attributed to the lagoons, as upgradient wells also contain significant contaminant levels. Nonetheless, a concern does arise when groundwater elevations and the NUS auger borings are compared. The top of the water table aquifer underneath the lagoons varies in depth from +17 MSL to +14 MSL according to well elevation measurements taken at selected dates. NUS borings indicate the presence of sludge at +13 and +15 MSL in the northern and southern sludge drying lagoons, respectively. The wide fluctuation in groundwater elevations is attributed to the effect of flood events on water table levels near a stream. This effect is known as "bank storage". Such a condition is believed to have existed on April 18, 1986, when the highest water levels, +17 MSL, in wells near the backfilled lagoons were recorded. Though an infrequent event, bank storage of this magnitude is a concern as it can result in groundwater contact with the sludge in the backfilled lagoons. Of further concern the Backfilled Lagoons Area was located in the 100 year flood plain. Subsequent backfilling has raised the surface of the lagoons above the 100 year flood plain.

In conclusion, it is apparent that sludge exists in all five backfilled lagoons, that volatile and base/neutral organics along with metals are contained in the sludges, and that a potential for contaminant leaching does exist. Of the five backfilled lagoons present, the two northernmost sludge drying lagoons contain the highest contaminant levels. Because all five lagoons are closed or "abandoned" facilities which contain contamination, they fall under CERCLA, and therefore will be further considered for remedial studies.

TABLE 3-3

MAXIMUM CONTAMINANT CONCENTRATIONS FOUND IN WELLS IN BACKFILLED LAGOONS AREA (ORGANICS IN ppb)

Compound	Upgradient of Backfilled Lagoons 0131	0176	Downgradient Sludge Drying Lagoons 0124	0125	Downgradient Settling Lagoons 0126	0127	Downgradient Oxidation Lagoon 0128	0129
trans-1,2-Dichloroethene		28*						
Tetrachloroethene	2600*	12*						
Trichloroethene	980*	38*						
Toluene	870				11			
Benzene	24							
Chlorobenzene	3300*		(174)		82(45)		110(97)	
Ethylbenzene				(130)	67		(21)	
1,2-Dichlorobenzene	2300(1500)	3160	89		76		37	
Naphthalene	130	152	86		(93)			
trans-1,2-Dichloroethene	14	32					(6)	
1,2,4-Trichlorobenzene	(627)		(105)					
Nitrobenzene					(52)			
Phenol	496				(121)	(10)	(160)	(20)
Aniline	1300*							

Blank Space - analyzed for but not detected.

* - NUS Data.

( ) - Analytical data obtained by Ciba-Geigy contractor prior to 1983.

A concentration without ( ) or * refers to data obtained by AWARE Inc. by September 1985.

3.3.2 Drum Disposal Area

The Drum Disposal Area covers 5.3 acres and is located between the Wastewater Treatment Plant and the Lime Sludge Disposal Area (Figure 3-1). The Drum Disposal Area and the Lime Sludge Disposal Area jointly comprise the area known as the Closed Chemical Landfill. The date at which drum disposal commenced in this area is not certain. This site was originally part of a large, unlined, settling lagoon (Cesareo and Morales, 1980). Aerial photos show active use of this lagoon up to 1956 (EPIC, 1984). Based on aerial photographs, it appears that the lagoons were out of service by 1962, and mounded material and debris were deposited within this area. Drums are evident in 1965 photos. State regulations passed in 1975 required landfills receiving chemical wastes to be lined with leachate collection/treatment systems. As a result, construction of a new landfill was commenced on site, and the Drum Disposal Area was officially closed by 1977 (Catalytic, 1977). On closure the site was regraded to prevent water ponding or erosion, overlain with a 30-mil PVC membrane, covered with a minimum of 2 feet of topsoil, and seeded. The PVC liner terminated under asphalt swales to channel runoff. Six vent pipes were installed for releasing gases generated within the landfill.

The size of the Drum Disposal Area as reported by background sources has varied. Landfill surface area estimates range from 62,000 ft^2 (Markewicz, 1976) to approximately 90,000 ft^2 (TRW, 1976). Drums are reportedly in three lifts with 4 feet of dirt between each lift (TRW, 1976). Therefore, the assumption that a typical drum is 3 feet high results in a total disposal height of 17 feet. This height closely corresponds to the depth which would be available if the landfill base is at +35 feet MSL (Catalytic, 1977) and the surface relief varies from +50 feet to +58 feet MSL. There are 92,000 drums reportedly in the Drum Disposal Area (Bobsein, 1977). Therefore, the assumption that a drum covers 4 square feet and that there are three lifts produces a surface area of 122,700 ft^2. This estimate is larger than the above-reported values but fits well within the size shown in photos and on surface relief maps.

Wastes deposited in the Drum Disposal Area are broken down into three categories which are defined as resin residue, clarification residue, and distillation residue. These wastes were packaged in 55-gallon, light gauge steel, open head drums; however, some of the clarification residues were reportedly deposited in bulk (Catalytic, 1977). The resin residues are a sidestream from the clarification process of epoxy resin products. This waste contains filter paper, cartridges, clay, and diatomaceous earth used in product filtration and clarification. These residues are impregnated with resins and by-products from the manufacturing process. These by-products would likely consist of unreacted organics and traces of the solvent reaction media. The clarification residues are similar to the resin residues in that they are a sidestream of a product clarification process. The difference is that the products manufactured are dyes and pigments; these involve the use of heavy metals in addition to organics (TRC, 1975). Some of these wastes were reportedly deposited in bulk. The final wastes are distillation residues, which are the "bottoms" resulting from the distillation of the solvent media used in the manufacture of dyes and pigments. Total drums of waste are estimated to be broken down as follows: 63,000 drums are resin residues, 15,000 drums are clarification residues, and 14,000 drums are distillation residues (Bobsein, 1977). Drums were supposedly labeled at the time of disposal. At this time these labels are probably illegible and the drums badly rusted due to their long-term presence in the ground. However, the actual condition is unknown until a test excavation is completed. Table 3-4 gives the breakdown of a predisposal analysis of drummed waste performed by Ciba-Geigy in 1975. A further breakdown of some of the key organics alluded to in Table 3-4 is presented in Table 3-5, which gives a list of organics that may be held within the solid matrix of the drummed wastes.

Geophysical investigation and groundwater analysis in the vicinity of the Drum Disposal Area were begun by Ciba-Geigy prior to 1983. The following relationships were derived after examining the groundwater characteristics downgradient of the Drum Disposal Area:

(1) Terrain conductivity "plumes" closely approximate areas underlain by inorganically contaminated groundwater;

TABLE 3-4
PREDISPOSAL ANALYSES OF DRUMMED WASTES BURIED IN THE DRUM DISPOSAL AREA

Analysis	Epoxy Resin Residues[1] Total mg/kg in Waste	Epoxy Resin Residues[1] mg/kg Remaining in Extracted Residue	Clarification Residues[2] Total mg/kg in Waste	Clarification Residues[2] mg/kg Remaining in Extracted Residue	Distillation Residues[3] Total mg/kg in Waste	Distillation Residues[3] mg/kg Remaining in Extracted Residue
pH	10.1 pH units		9.7 pH units			3.3 pH
Chemical Oxygen Demand		30,921		16,000		43,900
Phenols	11	0	NF	NF	0.5	NF
Phosphorous	14	4	11	4	1	1
Sulfate	150	150	1,157	977	1,700	150
Chloride	98,000	57,000	1,600	200	16,000	16,000
Total Dissolved Solids		136,000		8,000		6,910
Cadmium	0.1	NF	0.1	NF	0.1	NF
Chromium (total)	3	NF	180	NF	3	1

See footnotes at end of table.

TABLE 3-4 (CONT'D)

PREDISPOSAL ANALYSES OF DRUMMED WASTES BURIED IN THE DRUM DISPOSAL AREA

Analysis	Epoxy Resin Residues[1]		Clarification Residues[2]		Distillation Residues[3]	
	Total mg/kg in Waste	mg/kg Remaining in Extracted Residue	Total mg/kg in Waste	mg/kg Remaining in Extracted Residue	Total mg/kg in Waste	mg/kg Remaining in Extracted Residue
Copper	1	NF	386	3	67	33
Iron	1	NF	2,400	2	300	250
Lead	0.1	NF	4	1.0	2	2
Manganese	1	NF	957	NF	3	3
Zinc	2	NF	5	NF	2	2
Flash Point	165°C		200°C		82°C	
Chlorinated Hydrocarbons		NF		NF		5
Chlorinated Hydrocarbons[4]		NF		17,000		20,800

---

[1] No metals used in process.
[2] From dye production.
[3] Solid residues from distillation of dye materials.
[4] Via ether extract; all others extracted with water adjusted to pH 6.
NF--Not found (the limit of detection was not specified).
SOURCE: TRC, 1975.

TABLE 3-5

QUANTITY OF "SELECTED SUBSTANCES" DISPOSED OF IN THE DRUM DISPOSAL AREA

	Amount (pounds)
Chlorobenzene(a)	141,000
1,2-Dichlorobenzene(a)	69,000
1,2,4-Trichlorobenzene(a)	12,000
Nitrobenzene(a)	19,700

(a) These four materials are present in low concentrations in solid residues from solvent recovery operations.

SOURCE: TRC, 1981

(2) Areas underlain by organically contaminated groundwater coincide essentially with the inorganics "plume" and with the terrain conductivity "plumes" but tend to be more extensive, particularly in the downgradient direction.

Conclusions based on geophysical surveys conducted during the RI indicate that the shallow groundwater in the area between the components of the closed chemical landfill and the Cardinal Drive Area east of the plant is contaminated. The Drum Disposal Area is a source of this contamination.

Groundwater monitoring data are available for a number of Ciba-Geigy wells immediately downgradient of the Drum Disposal Area and from one well along the western or upgradient border of the disposal area. These wells were sampled by Ciba-Geigy's own consultants. Table 3-6 summarizes the maximum concentrations of organic contaminants detected in these wells. Initial sampling activity was conducted prior to 1983. A comparison of analytical results from upgradient well 0109 with results from six downgradient wells shows slight to severe increases in concentrations of metals and various organic compounds. The metals found at elevated levels included As, Cr, Cu, Fe, Pb, and Zn. Well 0111, located between the Drum Disposal Area and the Lime Sludge Disposal Area, exhibited very high concentrations of benzene, naphthalene, and several aliphatic and aromatic chlorinated organics. Only one of these compounds, chlorobenzene, was detected in upgradient well 0109.

In September 1985, AWARE Inc. sampled the same wells previously mentioned. Well 0109 was free of organic contaminants. Comparatively, wells 0106/0106A*, 0108/0108A, 0110/0110A, 0111, 0117, and 0137 exhibited moderate to severe concentrations of various organics. Again, well 0111 displayed the highest degree of contamination ranging from 110 ug/L naphthalene to 15,000 ug/L nitrobenzene. The most frequently detected compounds were (1) chlorobenzene in all six downgradient wells; and (2) tetrachloroethene in five of the six wells.

*A well designated as such indicates that the original, numbered well, was replaced by Ciba-Giegy with a new well. The new well is indicated by the letter "A".

TABLE 3-6
MAXIMUM CONCENTRATIONS OF CONTAMINANTS IN GROUNDWATER NEAR THE DRUM DISPOSAL AREA
(ORGANICS IN ppb, METALS IN ppm)

	Upgradient Wells	Downgradient Wells					
Compound	0109	0106/ 0106A	0108/ 0108A	0110/ 0110A	0111	0117	0137
Chloroform				(1)	1400		(81)
Trichloroethene		(7)	(180)	(22)	(800)		(13)
Tetrachloroethene		(20)	(89)	(21)	6000		(60)
trans-1,2-Dichloroethene			(70)	(24)	(170)		
1,2-Dichloroethane			(157)				
Benzene		15(2)	16	(5)	2400	(405)	(12)
Toluene	(3)	(3)	(44)		14000	(2300)	(23)
Chlorobenzene	(157)	15	14(204)	(95)	(8400)	1800	8700
Ethylbenzene			(2)		1700	(126)	
1,2-Dichlorobenzene		(57)	(724)	(906)	3800	1300	3400
1,3-Dichlorobenzene				(1.8)	30		
1,4-Dichlorobenzene				(57)			

See footnotes at end of table.

TABLE 3-6 (CONT'D)
MAXIMUM CONCENTRATIONS OF CONTAMINANTS IN GROUNDWATER NEAR THE DRUM DISPOSAL AREA
(ORGANICS IN ppb, METALS IN ppm)

	Upgradient Wells	Downgradient Wells					
Compound	0109	0106/ 0106A	0108/ 0108A	0110/ 0110A	0111	0117	0137
1,2,4-Trichlorobenzene			(68)	(59)	(781)	(409)	
Nitrobenzene		(35)			15000		(139)
Naphthalene			(102)	(193)	110(168)	(236)	630
Arsenic		(0.05)		(0.01)	(0.06)		
Chromium	(0.04)	(0.07)	(0.18)	(0.06)	(0.10)	(0.37)	
Copper	(0.14)	(0.17)			(0.99)	(1.6)	
Iron	(22.8)	(74.6)	(64)	(15.3)	(65)	(6.3)	
Lead	(0.02)	(0.021)	(0.10)	(0.03)	(0.10)	(0.115)	
Mercury	(0.025)	(0.008)	(0.0058)	(0.005)	(0.0048)	(0.003)	
Zinc	(0.08)		(0.673)		(0.53)	(1.8)	

Blank Space - analyzed for but not detected.

( ) - Analytical data obtained by Ciba-Geigy contractor prior to 1983.

A concentration without ( ) refers to data obtained by AWARE Inc. in September 1985.

0106/0106A - Designates an older well which was subsequently replaced by a new unit as designated by the letter "A".

During the hydrogeologic investigation conducted by AWARE in 1985, it was concluded that well 0111 was not accurately reflecting the potentiometric levels of the Primary Cohansey (AWARE, 1986). Additionally, water quality data from this well, as previously mentioned, had exhibited significantly higher levels of contamination than nearby wells screened in the Primary Cohansey. A decision was made to abandon the well. Upon removal of the PVC casing, the PVC casing had been perforated above the water table aquifer, beginning at a depth roughly coincident with the top of a clay unit. A granular, asphalt-like material appears to have flowed through this perforation(s) and down the well casing, staining its interior and collected in the lower 3.5 ft of the well screen. A sample of this material was submitted for priority pollutants +40 analyses. The results are summarized in Table 3-7. The results suggest that nonaqueous phase liquids (NAPLs) or sludge may be present in the vicinity of well 0111; however it has not been determined at this time if this material is below the water table or if it is restricted above a shallow clay unit. It should be noted that many of these compounds, particularly the benzene-based organics and heavy metals, closely parallel the contaminants that were reportedly deposited within the landfill (Tables 3-4, 3-5).

In conclusion, the Drum Disposal Area as an inactive facility continues to generate the uncontrolled release of hazardous substances to the underlying groundwater. As such, this source area falls under CERCLA for potential remedial measures. The area containing the landfill is well defined, though the actual location and volume of the buried waste areas are unknown. However, many of the questions cannot be easily answered until excavations are performed. In addition, the close correlation between groundwater contaminants and reported predisposal waste analyses gives a general characterization of the waste. As a result, the disposal area (buried wastes and contaminated soils) will be reviewed for further remedial studies; however, the positive identification and extent of the NAPL contamination is unknown and would require further characterization work.

TABLE 3-7

ANALYTICAL RESULTS OF GRANULAR MATERIAL FOUND IN WELL 0111 WELL (ALL CONCENTRATIONS IN ug/kg)

Parameter	Concentration
Tetrachloroethene	560,000
Toluene	200,000
Chlorobenzene	330,000
Ethylbenzene	140,000
1,2-Dichlorobenzene	200,000
1,4-Dichlorobenzene	60,000
Nitrobenzene	270,000
1,2,4-Trichlorobenzene	3,400,000
Naphthalene	190,000
2-Methylnaphthalene	9,200
2,4,5-Trichlorophenol	300,000
Phenanthrene	50,000
Di-n-butyl phthalate	720,000
Fluoranthene	13,000
Pyrene	20,000
Bis(2-ethylhexyl) phthalate	210,000
Aroclor 1242	12,000,000
Arsenic	17,000
Chromium	12,000
Copper	640,000
Mercury	19,000
Nickel	7,300
Selenium	1,300
Zinc	62,000
Phenolics	56,000
Total Organic Carbon	19,000,000

SOURCE: AWARE, 1986

3.3.3 Lime Sludge Disposal Area

The Lime Sludge Disposal Area was used from 1952 to 1977 and is the second of the two Closed Chemical Landfill components. This area covers 3.9 acres according to surface contour maps and air photos (EPIC, 1984). The base of the disposal area is at +50 feet MSL (Cesareo and Morales, 1980), and Ground Penetrating Radar (Weston, 1984) sharply defined the waste cells and found no evidence of buried drums. In addition, aerial photos distinctly show the waste cells. Based on this information, waste quantity was estimated at 49,600 yd^3 using the contour method. This waste consisted of calcium carbonate sludge formed during the neutralization of wastewater at the plant treatment facility (Cesareo and Morales, 1980). The Lime Sludge Disposal Area was closed in 1977 along with the Drum Disposal Area. Closure consisted of a graded sand cover, a 30-mil PVC liner, and 2 feet of topsoil with seed (Catalytic, 1977). Paved diversion swales surround the area to control runoff.

The major contaminants of concern which may be present are heavy metals entrapped in the lime sludge. Ten percent dolomitic lime slurry was added to water in the neutralization process at the wastewater treatment plant. As a result, any metals in the wastewater would be precipitated out as metal hydroxides and contained within the sludge which was subsequently landfilled in the Lime Sludge Disposal Area. Table 3-8 gives a list of metals which are expected to be present in the lime sludge according to Ciba-Geigy estimates.

There are no data available to conclusively indicate that the Lime Sludge Disposal Area is a major contributor to groundwater contamination. The occurrence of metals in wells downgradient of the Lime Sludge Disposal Area suggests that the this area may be a source. However, due to the close proximity of the Drum Disposal Area, the exact origin of the metal contamination is not definable. Conclusions cannot be derived until borings are completed in this area and the sludge samples obtained are tested for their ability to leach metals of concern.

TABLE 3-8

METALS DISPOSED OF IN THE LIME SLUDGE DISPOSAL AREA BETWEEN 1952 AND 1977

	Amount (pounds)
Copper(a)	180,000
Chromium(a)	120,000
Zinc(a)	48,000
Mercury(a)	6,000
Lead(a)	30,000
Arsenic(b)	Unknown

(a) These metals are present in lime at low concentrations as the low-solubility hydroxides generated by wastewater treatment (TRC, 1981).

(b) It is reported that approximately 10 percent of the waste lime disposed of at the Lime Sludge Disposal Area included calcium arsenite (Cesareo and Morales, 1980) of an unknown concentration.

In summary, the Lime Sludge Disposal Area offers a limited potential for groundwater contamination, but no remedial decisions can be made until source sampling is completed. The facility does warrant interest in that it is a closed disposal facility and thus falls under CERCLA.

3.3.4 Filtercake Disposal Area

The Filtercake Disposal Area covers approximately 12 acres and is located about 2,500 feet south southeast of the Production Area (Figure 3-1). The site was used between 1952 and 1977 for the disposal of dried sludge from wastewater treatment operations. Aerial photos of this location (EPIC, 1984) show evidence of activity along with debris deposited in this area in 1956. In addition, drums appear evident in 1961 photos. As there was no indication from aerial photos of drum disposal activity in the Drum Disposal Area prior to 1962, the Filtercake Disposal Area may have acted as either a temporary or permanent repository up to that time. In all photographs, it is clear that sludge and material were deposited randomly throughout the area with apparently no formal construction of a designed waste facility. The site has a varying bottom elevation, and was covered with a soil layer and seeded on closure (Cesareo and Morales, 1980). Ground Penetrating Radar confirmed the variance of the Filtercake Disposal Area subsurface structure. There is no impermeable lining or cap. Soil sampling by NUS Corporation Region 2 FIT found the cover soil to be inadequate, resulting in exposed sludge and erosion along the northern slope of the Filtercake Disposal Area.

Figure 3-9 shows the approximate locations of borings completed in the Filtercake Disposal Area. Two auger borings completed by NUS Corporation Region 2 FIT, RI-A-6 and RI-A-7 (Figures 3-10 and 3-11), and two auger borings completed by AWARE Corporation (MA-1 and MA-2) found a varying bottom depth in the Filtercake Disposal Area (AWARE, 1986). Three additional borings labeled MASC-1, MASC-2, and MASC-3 were completed by AWARE in 1987 and were used along with hand auger borings to determine the depth and extent of the Filtercake Disposal Area (AWARE, September 1987). The bottom elevation of the sludge layer exists between +39 MSL and +28 MSL, with an average bottom elevation

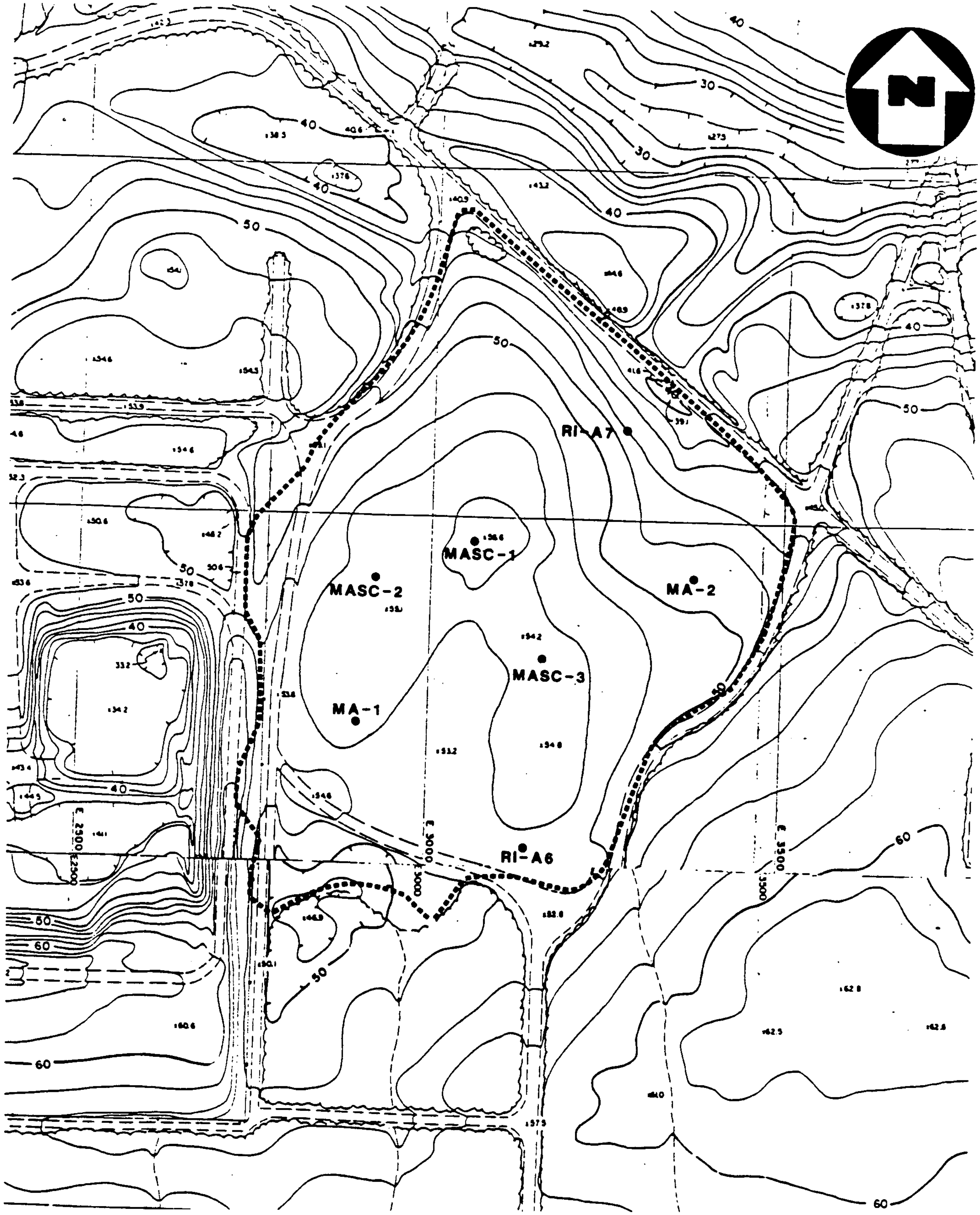


FIGURE 3-9

FILTERCAKE DISPOSAL AREA BORING LOCATIONS CIBA-GEIGY, TOMS RIVER, N.J.

APPROXIMATE SCALE - 1" = 200'

NUS CORPORATION

NUS CORPORATION

TDD NO. 02-8408-04B
PROJECT NAME Toms River Chemical Co.
LOCATION RT-A-6
DIAMETER : CASING ID N/A
ROCK CORE N/A
COORDINATES: NORTH −2967
EAST 3205
CONTRACTOR A.C. Schultes & Sons, Inc. LOGGED BY ______
DRILLING METHOD Hollow Stem Auger

DATE: START 9/13/85 FINISH 9/16/85
ELEVATIONS Above Mean Sea Level
GROUND SURFACE +52.7
GROUND WATER ______
DEPTH OF HOLE 36.0'
OVERBURDEN N.A. ROCK N.A.
DIP N.A.
CHECKED BY R. TEIFKE
SHEET 1 OF 2

GEOLOGIC PROFILE

DEPTH (FT.)	ELEV. (FT.)	SYM BOL	SAMPLE TYPE AND No.	SAMPLE BLOWS OR REC.	SAMPLE DEPTH RANGE (FT.)	ROD %
			SS-1 BW 22	3-2-2-5	2-4	0.80
5			SS-2 BW 23	18-20-24-23	4-6	2.00
			SS-3	26-19-15-19	6-8	1.60
10			SS-4 BW 24	19-28-20-17	8-10	1.50
			SS-5	10-15-15-17	10-12	1.30
			SS-6 BW 25	7-7-18-17	12-14	1.40
15			SS-7	8-14-19-22	14-16	1.25
			SS-8	14-18-14-16	16-18	1.40
			SS-9	11-1-10-17	18-20	1.30

ANALYTICAL RESULTS

BW 22

Tetrachloroethene	21000	Cr	1625
		Cu	2433
		Pb	321
		Hg	240
		Ni	26
		Va	120

BW 23

Cr	1659
Cu	1611
Pb	268
Hg	65

BW 24

Tetrachloroethene	21000	Cr	995
Toluene	5400	Cu	1057
Xylenes	990	Pb	186
		Hg	65

BW 25

Cr	936
Cu	1034
Pb	241
Hg	0.57
Va	35

SYMBOLS

- ■ SLUDGE
- ⁘ SAND/GRAVEL
- ▨ STAINED SAND
- ▩ CLAY

ANALYTICAL RESULTS

ORGANICS IN ug/kg
INORGANICS IN mg/kg

FIGURE 3-10

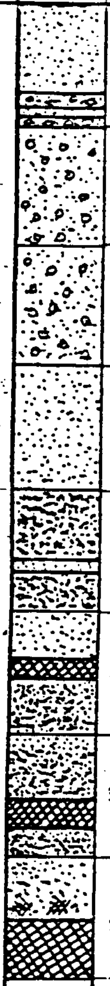
BOREHOLE LOG AND CHEMICAL ANALYSES

NUS CORPORATION

TDD NO. 02-8403-04B
PROJECT NAME Toms River Chemical Co.
LOCATION RI-A-6
DIAMETER: CASING ID N/A
ROCK CORE N/A
COORDINATES: NORTH -2967
EAST 3205
CONTRACTOR A.C. Schultes & Sons Inc.
LOGGED BY J. Grelis
DRILLING METHOD Hollow Stem Auger

DATE: START 9/13/85 FINISH 9/16/85
ELEVATIONS Above Mean Sea Level
GROUND SURFACE + 52.7
GROUND WATER
DEPTH OF HOLE 36.0'
OVERBURDEN N.A. ROCK N.A.
DIP N.A.
CHECKED BY R. Teifke
SHEET 2 OF 2

GEOLOGIC PROFILE



DEPTH (FT.)	ELEV. (FT.)	SAMPLE TYPE AND No.	SAMPLE BLOWS OR REC.	SAMPLE DEPTH RANGE (FT.)	ROD %	ANALYTICAL RESULTS
		SS-10	15-18-25-20	20-22	1.40	
		SS-11	10-18-19-24	22-24	1.30	
25		SS-12	15-21-25-36	24-26	1.30	
		SS-13	15-18-22-26	26-28	1.35	
		SS-14	10-16-23-17	28-30	1.25	
30		SS-15	0-17-18-20	30-32	1.30	
		SS-16	7-10-13-23	32-34	2.00	
35		SS-17	9-12-13-19	34-36	2.00	

SYMBOLS

- ■ SLUDGE
- ⁙ SAND/GRAVEL
- ▒ STAINED SAND
- ▩ CLAY

ANALYTICAL RESULTS

ORGANICS IN ug/kg
INORGANICS IN mg/kg

FIGURE 3-10(cont.)

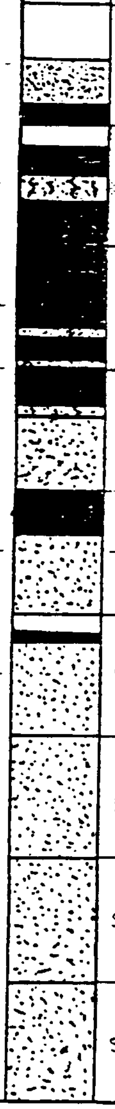
BOREHOLE LOG AND CHEMICAL ANALYSES

NUS CORPORATION

TDD NO. 02-8408-04B
PROJECT NAME Toms River Chemical Co.
LOCATION RI-A-7
DIAMETER : CASING ID N/A
ROCK CORE N/A
COORDINATES: NORTH −2330
EAST 3222
CONTRACTOR A.C. Schultes & Sons, Inc. LOGGED BY J. Grelis
DRILLING METHOD Hollow Stem Auger

DATE: START 9/16/85 FINISH 9/17/85
ELEVATIONS Above Mean Sea Level
GROUND SURFACE +47.3
GROUND WATER
DEPTH OF HOLE 38.0'
OVERBURDEN N.A. ROCK N.A.
DIP N.A.
CHECKED BY R. TEIFKE
SHEET 1 OF 2

GEOLOGIC PROFILE



DEPTH (FT.)	ELEV. (FT.)	SYMBOL	SAMPLE TYPE AND No.	SAMPLE BLOWS OR REC.	SAMPLE DEPTH RANGE (FT.)	ROD %
			SS-1	6-4- 2-2	2-4	1.90
5			SS-2 BW 2B	4-2- 1-1	4-6	1.60
			SS-3 BW 29	9-6- 6-17	6-8	2.00
			SS-4	12-20- 22-28	8-10	2.00
10			SS-5	12-12- 9-23	10-12	1.90
			SS-6	14-13- 14-23	12-14	1.70
15			SS-7	10-15- 17-41	14-16	1.45
			SS-8	13-17- 19-20	16-18	1.60
			SS-9	7-15- 17-21	18-20	1.30

ANALYTICAL RESULTS

BW 2B

2-Hexanone	170	Cr	909
Tetrachloroethene	39	Cu	1217
		Pb	142
		Hg	64
		Zn	646

BW 29

1,1,2,2-Tetrachloroethane	50	Cr	396
2-Hexanone	470	Cu	449
4-Methyl-2-Pentanone	330	Pb	76
Tetrachloroethene	30	Hg	0.38
		Zn	291

SYMBOLS

■	SLUDGE
⁘	SAND/GRAVEL
⁙	STAINED SAND
▨	CLAY

ANALYTICAL RESULTS

ORGANICS IN ug/kg
INORGANICS IN mg/kg

FIGURE 3-11

BOREHOLE LOG AND CHEMICAL ANALYSES

NUS CORPORATION

TDD NO. 02-8408-04B
PROJECT NAME Toms River Chemical Co.
LOCATION RI-A-7
DIAMETER: CASING ID N/A
ROCK CORE N/A
COORDINATES: NORTH −2330
EAST 3222
CONTRACTOR A.C. Schultes & Sons, Inc LOGGED BY J. Grelis
DRILLING METHOD Hollow Stem Auger

DATE: START 9/16/85 FINISH 9/17/85
ELEVATIONS Above Mean Sea Level
GROUND SURFACE +47.3
GROUND WATER
DEPTH OF HOLE 38.0'
OVERBURDEN N.A. ROCK N.A.
DIP N.A.
CHECKED BY R. Teifke
SHEET 2 OF 2

GEOLOGIC PROFILE

DEPTH (FT)	ELEV. (FT.)	SYMBOL	SAMPLE TYPE AND No.	SAMPLE BLOWS OR REC.	SAMPLE DEPTH RANGE (FT)	ROD %	ANALYTICAL RESULTS
		⁘	SS-10	10-13- 13-16	20-22	1.50	
		⁘	SS-11	15-17- 18-23	22-24	1.50	
25		☒					
		⁘	~~SS-12~~ BW 30	8-9- 14-15	26-28	~~1.80~~	BW 30 Toluene 5.7 Chlorobenzene 6.8 Cr 7.7 Pb 5
		⁘	SS-13	4-4 4-4	28-30	1.30	
30		▩	SS-14	1-6- 2-19	30-32	1.90	
		▩	SS-15	7-10- 14-18	~~32-34~~	~~2.00~~	
35		▩	SS-16	3-8- 23-29	34-36	1.70	
		▩	~~SS-17~~ BW 31	0-1- 10-20	36-38	2.00	BW 31 2-Hexanone 40 Tetrachloroethene 9 Toluene 5.8 Cr 250 Cu 302 Pb 19 Zn 234 Va 40 Hg 1.9

SYMBOLS

■	SLUDGE
⁘	SAND/GRAVEL
⁙	STAINED SAND
▩	CLAY

ANALYTICAL RESULTS

ORGANICS IN ug/kg
INORGANICS IN mg/kg

FIGURE 3-11 (cont.)

BOREHOLE LOG AND CHEMICAL ANALYSES

of +35 MSL according to NUS boring logs. An initial rough estimate of the sludge volume, based on the average thickness of the sludge layers found in the area of the site, is 69,500 yd^3. AWARE estimates a sludge volume of 87,000 yd^3 (AWARE, September 1987).

Chemical analyses were performed on sludge samples from this area (Table 3-2). Because the sludge landfilled here was originally from wastewater treatment operations, the contaminants found were similar to those found in the backfilled lagoons, with the exception of two chlorinated aliphatic compounds. AWARE duplicated the NUS analysis by using the 1987 borings and found similar compounds from which the same conclusions can be derived (AWARE, September 1987).

Analysis of wells upgradient and downgradient of the site indicates that the Filtercake Disposal Area is contributing to groundwater contamination. Table 3-9 outlines the results from the past sampling of wells. A higher concentration of chlorinated aliphatics was found downgradient of the Filtercake Disposal Area as compared to upgradient. In addition, some aromatics found in the Filtercake Disposal Area sludge were found in downgradient wells only, though at lower concentrations than the aliphatic compounds. This is attributed to the fact that these chemicals are more soluble in water than many of the aromatics detected in the sludge samples. As a result, they would migrate faster and therefore be the first compounds to be detected in any contaminant plume formation. Upgradient wells for the Filtercake Disposal Area are downgradient of other source areas (Closed Chemical Landfill and Active Landfill) and thus give a fair representation of the groundwater entering in the Filtercake Disposal Area.

TABLE 3-9
MAXIMUM CONTAMINANT CONCENTRATIONS FOUND IN WELLS IN THE FORMER FILTERCAKE DISPOSAL AREA
(ORGANICS IN ppb AND METALS IN ppm)

Compound	Upgradient Wells			Downgradient Wells							
	0103/ 0103A	0104/ 0104A	0161	0119	0120	0121	0142	0154	0155	0156	0157
Benzene		190(140)	63*	63*		(10)	33	27	27	220	120
Chlorobenzene		690(140)	470*	470*		(372)	94	2000	9500	530	100
1,2-Dichlorobenzene		160				59	21	760	140	230	71
Naphthalene		10							270	17	47
Nitrobenzene		(73)								(0.005)	
Chloroform		(80)		(0.04)	(0.05)	(0.029)					
Trichloroethene		270	240*	(0.41)	(7.1)	(0.097)	46			300	
Tetrachloroethene		(140)	260*	(66)	(2.1)	(41.8)	44				
Ethylbenzene		(4)		(0.06)		(0.073)					
1,2-Dichloroethane				(0.0085)	(0.0037)	(0.0008)		(0.003)	(0.08)		
1,2,3-Trichlorobenzene				(0.35)	(0.05)	(2.775)	(0.06)	(0.09)		(0.20)	(0.07)
1,2,4-Trichlorobenzene						(202)	33(43)	(17)	(26)	(51)	(387)
1,4-Dichlorobenzene						(2717)	94(49)	(2664)	(1047)	(284)	(449)
Toluene						(1050)59	21(55)	760(74)	230(160)	71(158)	71(158)
trans-1,2-Dichloroethene			140*		(179)	28			270(181)	17	4.7
1,3-Dichlorobenzene								(1239)	(117)	(639)	(169)
Methylene chloride						(108)	(22)				
Arsenic						(285)	(23)	(211)	(151)	300(1464)	(546)
Chromium		(0.25)				(1482)	(32)	(467)	(133)	(179)	(391)
Copper	(0.53)	(0.05)				(30)					
Iron	(62)	(26)		(12)						160	
Lead	(0.49)				(998)						
Mercury	(0.001)	(0.0006)			(455)			(254)	(166)	(300)	
Zinc	(0.02)	(0.09)				(170)					(77)

Blank Space - analyzed for but not detected.
( ) - Analytical data obtained by Ciba-Geigy contractor prior to 1983.
A concentration without ( ) refers to data obtained by AWARE Inc. by September 1985.
* - NUS Data

In conclusion, it can be seen that the Filtercake Disposal Area is a source of groundwater contamination by organic chemicals and as a closed or inactive facility should be further considered for potential remediation under CERCLA.

3.3.5 Wastewater Treatment Plant Area

The wastewater treatment system at Ciba-Geigy was continually upgraded and modified since the facility began operations in 1952. The plant discharged wastewater to the Toms River from 1952 to 1966 and to the Atlantic Ocean from 1966 to the present. The original plant was south of the Production Area and had an equalization basin, oxidation lagoon, and settling basin (Figure 3-12). Later treatment plant modifications consisted of the addition of a second, smaller equalization basin, a neutralization basin with a slaked dolomite feed, a primary clarification system, three lagoons in series for secondary treatment, and two sludge drying lagoons (Figure 3-13). The five lagoons replaced the original oxidation lagoon and settling basin and are the same lagoons as those adjacent to the Toms River as reviewed in Section 3.3.1. The third major wastewater treatment plant modification resulted in a system that consisted of two equal-sized equalization basins, a neutralization basin, three clarifiers, two powdered activated carbon sludge basins, and two secondary clarifiers. All were located south of the Production Area on site (NJDEP-DWR, NJPDES Permit, 1985). The sludge basins and secondary clarifiers replaced the three treatment lagoons, and a filter press replaced the two sludge drying lagoons adjacent to the Toms River (Cesareo and Morales, 1980). Figure 3-14 shows the configuration of this treatment plant along with the location of borings completed during remedial investigations by both NUS and AWARE. The current plant, which began operation in 1987, includes aboveground enclosed equalization tanks, which replaced the two equalization basins. In addition, the primary clarifiers have been covered to eliminate odors.

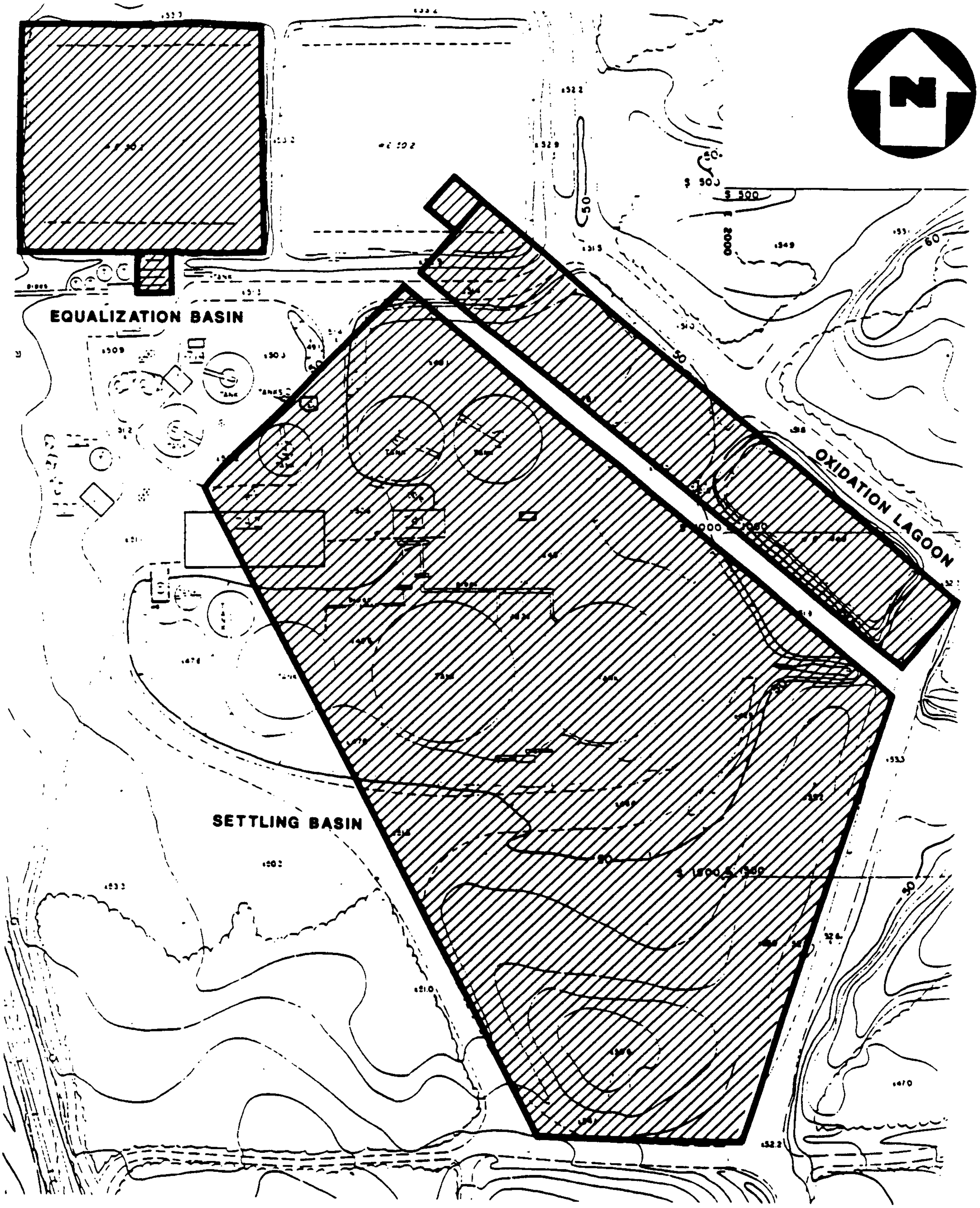


FIGURE 3-12

FIRST WASTEWATER TREATMENT PLANT

CIBA-GEIGY, TOMS RIVER, N.J.

APPROXIMATE SCALE - 1"= 200'

NUS CORPORATION

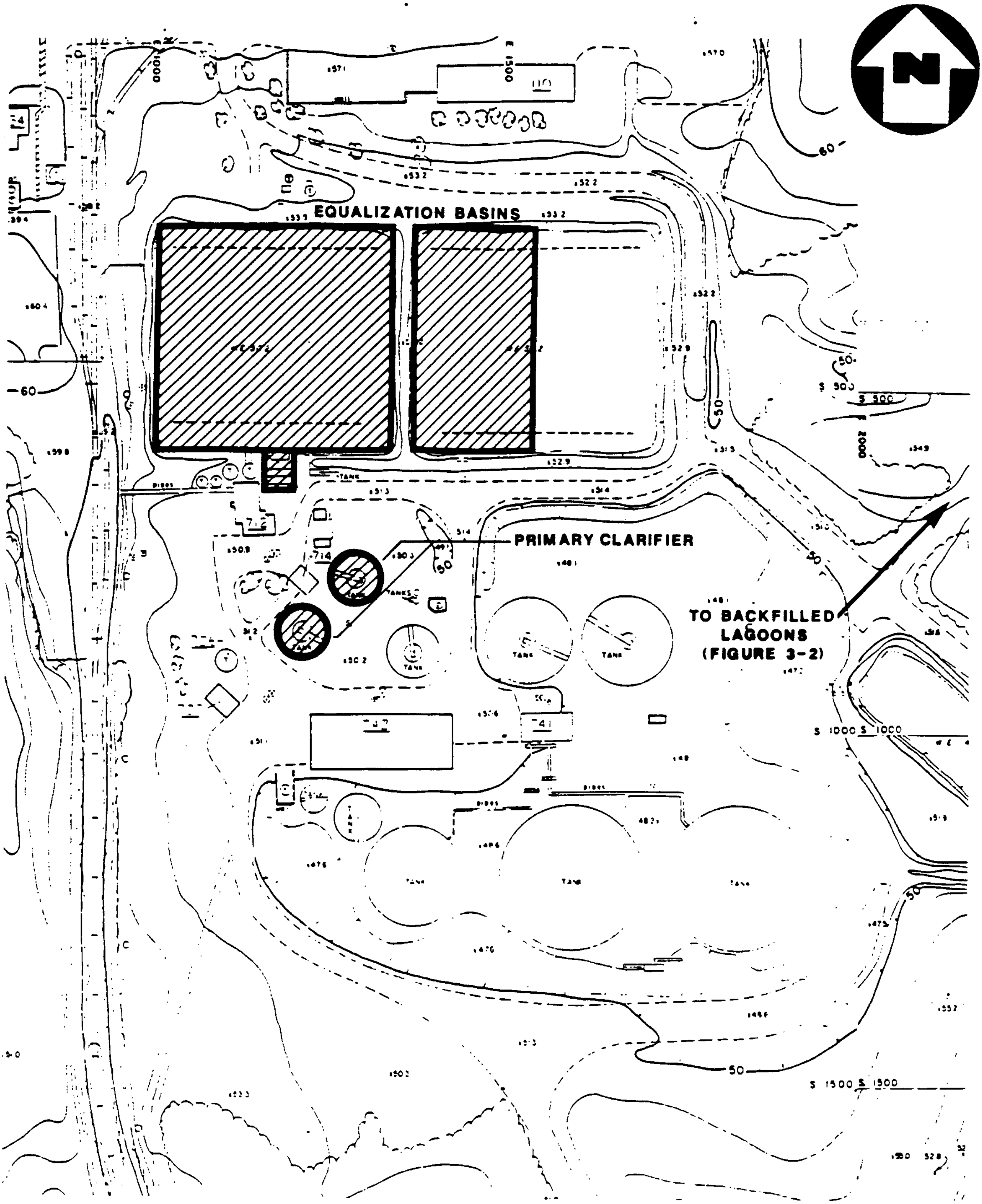


FIGURE 3-13

SECOND WASTEWATER TREATMENT PLANT

CIBA-GEIGY, TOMS RIVER, N.J.

APPROXIMATE SCALE - 1"= 200'

NUS CORPORATION

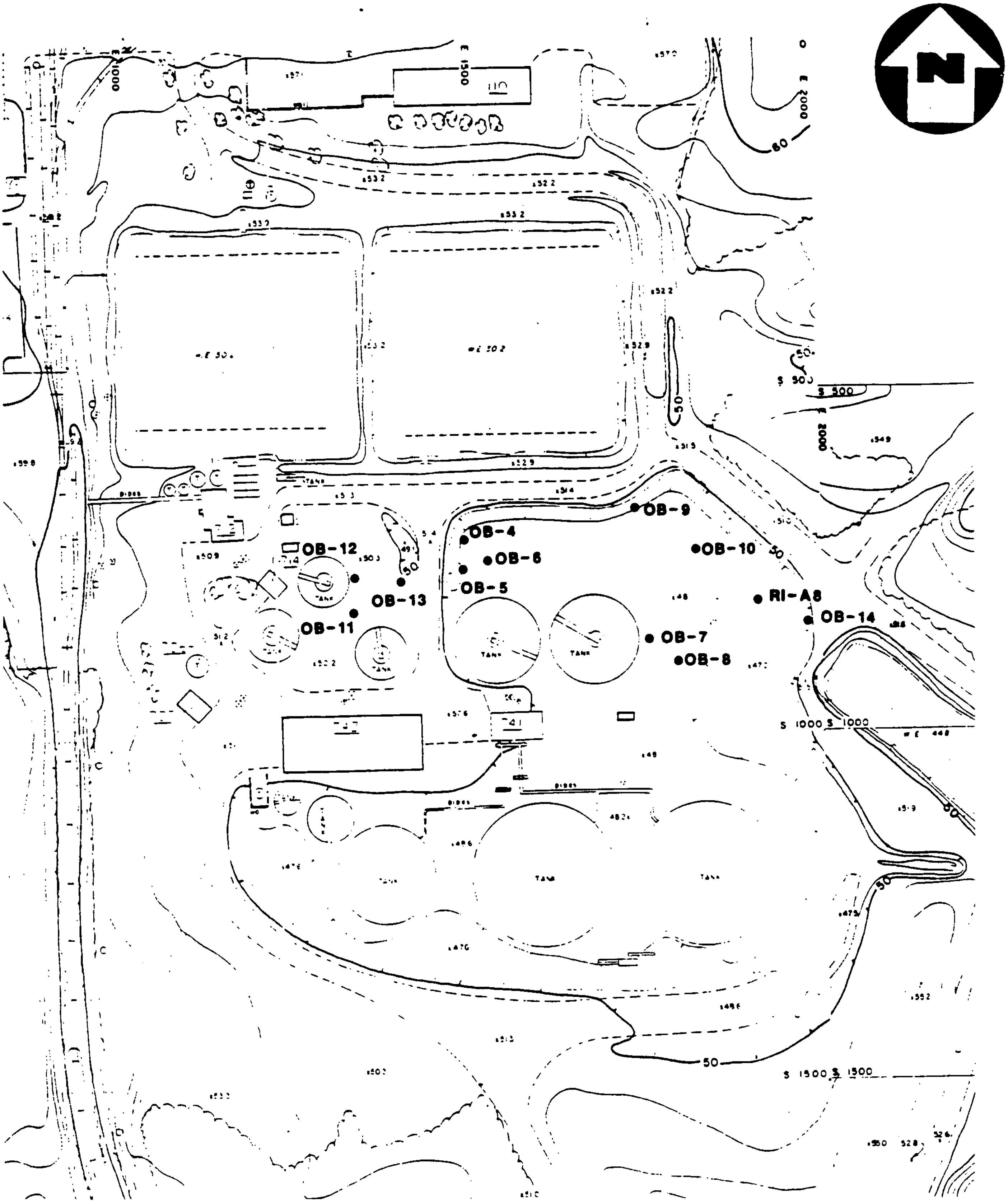


FIGURE 3-14

SOIL BORING LOCATIONS
THIRD WASTEWATER TREATMENT PLANT
CIBA-GEIGY, TOMS RIVER, N.J.

NUS CORPORATION

APPROXIMATE SCALE - 1" = 200'

NUS completed boring RI-A-8 in the area of the first treatment plant's oxidation lagoon. AWARE also completed borings OB-9, OB-10, and OB-14 in the same location (AWARE, 1986). Borings RI-A-8, OB-10, and OB-14 all encountered a thin, black sludge layer at varying elevations between +43 MSL and +33 MSL (5 to 10 feet below ground surface). The water table is between +19 MSL and +22 MSL. Chemical analysis of the sludge obtained from boring RI-A-8 (Figure 3-15) indicates the presence of some organics and, most notably, high concentrations of various heavy metals. One unique metal found was silver, which was probably used as a catalyst in organic syntheses during the manufacture of chemical products. These metals were in a dissolved form in the process wastewater treated at the plant. Subsequent neutralization processes utilizing lime and mechanical aeration would raise the pH and cause the metals to precipitate out with the sludge formed during treatment. Therefore, it could be concluded that the sludge layer found is likely a residual left from the former oxidation lagoon.

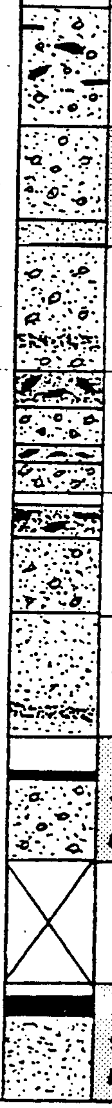
Aerial photographs (EPIC, 1984) from 1956 reveal the extent of this wastewater treatment plant. By 1962 aerial photography again shows the outline of the oxidation and settling basins; however, they appear to be out of service and drying out. The lower end of the settling basin became the Drum Disposal Area by 1965, and photographs from 1976 show extensive earth-moving activities in the old oxidation lagoon area and northern section of the old settling lagoon. In addition, the Drum Disposal Area is clearly evident as described in Section 3.3.2. Though sludge appears to be stockpiled in these photographs, the amount of sludge present is extensive and residuals may have been left. The east equalization basin was built over the northern tip of the former oxidation basin and, therefore, no auger borings could have been completed in this area. Additional AWARE borings in the area of the former settling basin (OB-4, OB-5, OB-6, OB-7, and OB-8) did not encounter any sludge with the exception of boring OB-6. Borings OB-11, OB-12, and OB-13 were completed in areas where no former wastewater treatment plant units were previously located. No sludge layer was encountered.

NUS CORPORATION

TDD NO. 02-8408-04B
PROJECT NAME Toms River Chemical Co
LOCATION RI-A-8
DIAMETER : CASING ID N/A
ROCK CORE N/A
COORDINATES: NORTH −0807
EAST 1879
CONTRACTOR A.C. Schultes & Sons Inc LOGGED BY J. Gretis
DRILLING METHOD Hollow Stem Auger

DATE: START 9/15/85 FINISH 9/15/85
ELEVATIONS Above Mean Sea Level
GROUND SURFACE +48.0
GROUND WATER
DEPTH OF HOLE 30.0'
OVERBURDEN N.A. ROCK N.A.
DIP N.A.
CHECKED BY R. TEIFKE
SHEET 1 OF 2

GEOLOGIC PROFILE



DEPTH (FT)	ELEV. (FT.)	SAMPLE TYPE AND No.	SAMPLE BLOWS OR REC.	SAMPLE DEPTH RANGE (FT)	ROD %
		SS-1	14-24-31-47	2-4	1.70
5		SS-2 BW 32	20-35-34-40	4-6	1.60
		SS-3	10-8-7-21	6-8	1.70
		SS-4	—	8-10	2.00
10		SS-5	13-25-41-40	10-12	1.70
		SS-6	15-17-17-26	12-14	1.30
15		SS-7 BW 33	17-22-29-32	14-16	1.40
		SS-8 BW 34	30-32-28-34	18-20	1.70

ANALYTICAL RESULTS

BW 32

Chlorobenzene	4.3	Cr	94
		Cu	96
		Pb	31
		Hg	2.6
		Zn	67

BW 33

		Zn	11
Toluene	41		
Chlorobenzene	22		
Exthlbenzene	5.7		
Xylenes	24		

BW 34

		Va	40
		Ag	37
	45	Cr	308
Toluene	120	Cu	307
Chlorobenzene	65	Pb	76
Xylenes	100	Hg	0.47
Exthylbenzene	23	Zn	227

SYMBOLS

■	SLUDGE
░	SAND/GRAVEL
▒	STAINED SAND
▩	CLAY

ANALYTICAL RESULTS

ORGANICS IN ug/kg
INORGANICS IN mg/kg

FIGURE 3-15

BOREHOLE LOG AND CHEMICAL ANALYSES

NUS CORPORATION

TDD NO. 02-8408-04B
PROJECT NAME Toms River Chemical Co.
LOCATION RI-A-9
DIAMETER: CASING ID N/A
ROCK CORE N/A
COORDINATES: NORTH −0807
EAST 1879
CONTRACTOR A.C. Schultes &
LOGGED BY
DRILLING METHOD Hollow Stem Auger

DATE: START 9/13/85 FINISH 9/13/85
ELEVATIONS Above Mean Sea Level
GROUND SURFACE +48.0
GROUND WATER
DEPTH OF HOLE 30.0'
OVERBURDEN N.A. ROCK N.A.
DIP N.A.
CHECKED BY R. TEIFKE
SHEET 2 OF 2

GEOLOGIC PROFILE

DEPTH (FT.)	ELEV. (FT.)	SYMBOL	SAMPLE TYPE AND No.	SAMPLE BLOWS OR REC.	SAMPLE DEPTH RANGE (FT.)	RQD %	ANALYTICAL RESULTS
		☒					
		░	SS-9	10-14- 17-22	22-24	—	
25		░	SS-10	—	24-26	—	
		░	SS-11	9-18- 22-25	26-28	—	
		░	SS-12 BW 35	10-20- 30-39	28-30		BW 35 Toluene 9.2 Cr 6.8 Hg 0.36
30							
35							

SYMBOLS

■	SLUDGE
░	SAND/GRAVEL
▒	STAINED SAND
▩	CLAY

ANALYTICAL RESULTS

ORGANICS IN ug/kg
INORGANICS IN mg/kg

FIGURE 3-15 (cont.)

BOREHOLE LOG AND CHEMICAL ANALYSES

Analysis of groundwater upgradient and downgradient of the wastewater treatment area indicates that contamination is migrating from the site, particularly from the area that was once covered by the northern end of the oxidation basin. This area has been since covered over by the east equalization basin. Wells 0133 and 0134 (Table 3-10) are close to the former oxidation lagoon area, and they contain aromatic hydrocarbons and chlorinated solvents. Metals are at low levels, and therefore, migration from this area could not be conclusively indicated. Equalization basins currently occupy the site, but they reportedly have impermeable liners that resist leakage (U.S. EPA, 1976); therefore, it is not known whether the contamination source is residue from the former oxidation lagoon or leakage from the current equalization basins.

In conclusion, buried sludge from the first wastewater treatment plant's oxidation lagoon underlies the current wastewater treatment plant. Chemical analysis of this sludge reveals the presence of aromatic hydrocarbons and heavy metals. Similar hydrocarbons were found in wells downgradient of the buried sludge, but metals analysis was inconclusive. However, equalization basins which were recently taken out of service were built over this area, and thus, the exact source of the groundwater contamination is not known. As the plant area is still active and monitored by the New Jersey Division of Water Resources, source area controls under CERCLA will not be considered at this time.

3.3.6 Active Landfill

The Active Landfill has been the only on-site repository for Ciba-Geigy's solid wastes since 1978. The multicelled facility is completely fenced and covers an area of approximately 18 acres with a bottom elevation of 40 feet above MSL. The first cell of the landfill operated under a 1-year permit (No. 1507C) issued in 1977. A 10-year permit (No. 1507D) was issued in 1978. In May 1982, Cell 1 was closed and disposal in Cell 2 began (Trautman, 1984). The landfill cells are double

TABLE 3-10
MAXIMUM CONTAMINANT CONCENTRATION FOUND IN WELLS IN THE CURRENT WASTEWATER TREATMENT PLANT AREA
(ORGANICS IN ppb AND METALS IN ppm)

Compound	Upgradient			Downgradient		
	0163	1102	1103	0133	0134	0164
Chlorobenzene				8300	1600	
Chloroform						51
Naphthalene				630	150	12
Benzene						
trans-1,2-Dichloroethene					750	
Chlorobenzene						
Toluene				2800	630	110
1,4-Dichlorobenzene						
Trichloroethene					2000	870
1,3-Dichlorobenzene						
Tetrachloroethene				12000	1900	3200
1,2,4-Trichlorobenzene						

See footnotes at end of table.

TABLE 3-10 (CONT'D)
MAXIMUM CONTAMINANT CONCENTRATION FOUND IN WELLS IN THE CURRENT WASTEWATER TREATMENT PLANT AREA
(ORGANICS IN ppb AND METALS IN ppm)

Compound	Upgradient			Downgradient		
	0163	1102	1103	0133	0134	0164
Nitrobenzene				39000	3500	
1,2-Dichlorobenzene						350
1,2-Dichloroethene						7
Arsenic						
Chromium						
Copper					(0.02)	
Iron						
Lead						
Mercury					(0.0022)	
Zinc					(0.2)	

Blank Space - analyzed for but not detected.

( ) - Analytical data obtained by Ciba-Geigy contractor prior to 1983.

A concentration without ( ) refers to data obtained by AWARE Inc. by September 1985.

lined (bottom and side slopes) with 30-mil PVC. In addition, the landfill includes a leachate collection system above the upper liner, a leak detection and collection system between the two liners, and the use of a lithium tracer to evaluate landfill peformance. Nine monitoring wells have been placed to monitor the surrounding groundwater quality (Cesareo and Morales, 1980).

The solid wastes that have been permitted for disposal in the Active Landfill have been divided into the following four general classifications (Environment Assessment Council, 1978):

- <u>Filter Cake from the Wastewater Treatment Plant</u>
  This material consists of a relatively dry cake (approximately 30 percent solids) produced by the pressure filtration of primary and secondary sludge from the wastewater treatment plant. This relatively inert material is classified by the Solid Waste Administration (SWA) as Type 12, Dry Sewage Sludge. This filter cake is disposed of in bulk along with iron oxide, calcium sulfate, and lime grit.

- <u>Epoxy Resin Residues</u>
  These wastes are a by-product of the clarification of insoluble epoxy resins. They contain resins, resin by-products, filter paper and cartridges, clay, and diatomaceous earth. The wastes are packaged in 55-gallon drums.

- <u>Clarification Residues</u>
  These are solid sludges or cakes resulting from the clarification of dyes and pigments. They contain insoluble dyes, pigments, iron oxides, clay, lime grit, and filter aids. Some of these wastes are packaged in 55-gallon drums, while others are disposed of in bulk.

- <u>Distillation Residues</u>
  These solid residues remain after the distillation of solvents used in the manufacture of insoluble dyes and pigments. They contain gypsum and residues of the dyes and pigments. The distillation residues are packaged in 55-gallon drums prior to disposal.

Table 3-11 presents the results of a predisposal analysis of filtercake sludge to be disposed of in Cell 2 of the Active Landfill.

The primary liners of both cells of the landfill have a reported history of leaking (Trautman, 1984). In 1979, Cell 1 was found to be leaking at the rate of 4 to 5 gallons per day (gpd) and gradually decreased to 1 quart per week in 1982. By May 1984, leakage in Cell 1 was occurring at the rate of 4 to 5 mL per day. The leakage rate from Cell 2 has been observed to range from 60 gpd in 1979 to 40 gpd in May 1984. During a routine inspection of the landfill in January 1984, two drums of toluene-contaminated material were discovered. Concentrations of toluene were 49 percent and 55 percent, respectively. On February 2, 1984, 34 drums of toluene-contaminated waste were removed from the landfill (Trautman, 1984). Enforcement activities by the NJDEP led to the removal of over 15,000 drums of waste from Cell 2 in 1985 and 1986.

Groundwater monitoring in the vicinity of the Active Landfill has been conducted by utilizing monitoring wells along the perimeter of the landfill. Table 3-12 presents a summary of maximum contaminant concentrations in these wells. Analytical data obtained prior to 1983 have been reported in the RAMP (CAI, 1983). At that time, only one of the three upgradient wells had been analyzed for organic priority pollutants. Well 0101 exhibited no detectable contaminants. Three downgradient wells (0105, 0107, 0123) were virtually free of organic contaminants. Well 0104, however, located along the western edge of the Filtercake Disposal Area, contained benzene and several chlorinated aliphatic and aromatic compounds at concentrations between 4 and 140 ug/L. It should be pointed out that this well is also located north of Cells 1 and 2 at a position adjacent to a future cell planned as Cell 5. It would appear that this well is not influenced by groundwater passing beneath Cells 1 and 2. The landfill site is underlain by an nonuniform clay layer which results in the formation of localized, perched water-table conditions.

TABLE 3-11
PREDISPOSAL ANALYSIS OF FILTERCAKE SLUDGE DISPOSED OF IN THE ACTIVE LANDFILL

Compounds Analyzed	Concentration	Compounds Analyzed	Concentration
Aniline	50 ppm*	Diphenylamine	50 ppm*
Aniline HCl	50 ppm*	Ethylbenzene	50 ppm*
Anisole	50 ppm*	Lead	151 ppm
Anthracene	50 ppm*	Mercury	29 ppm
Benzene	0.003 ppm*	4,4'-Methylene dianiline	50 ppm*
3-Chloroaniline	50 ppm*	Methyl isobutyl ketone	0.003 ppm*
4-Chloroaniline	50 ppm*	Naphthalene	50 ppm*
Chlorobenzene	50 ppm*	Nickel	80.5 ppm
2-Chloronitrobenzene	50 ppm*	Nitrobenzene	50 ppm*
4-Chloronitrobenzene	50 ppm*	2-Nitrophenol	50 ppm*
2-Chlorophenol	50 ppm*	Phenol	50 ppm*
Chromium (total)	354 ppm	1,4-Phenylene diamine	50 ppm*
Copper (total)	1,280 ppm	Toluene	50 ppm*
Cyanide	50 ppm*	Toluidines	50 ppm*
2,5-Dichloroaniline	50 ppm*	1,2,4-Trichlorobenzene	50 ppm*
1,2-Dichlorobenzene	20.5 ppm	1,1,1-Trichloroethane	0.003 ppm*
Diethyl phthalate	50 ppm*	Xylidines	50 ppm*
Di-n-butyl phthalate	50 ppm*	Zinc	140 ppm
Dimethylaniline	50 ppm*		

Note: Sludges were analyzed for materials used by Ciba-Geigy and for materials listed in the New Jersey Hazardous Waste Regulations, equivalent to the "Hazardous Constituents" in Appendix VIII, 40 CFR PART 261.

*Signifies that the component exists below the test's limit of detectability. The concentration recorded is the limit of detectability.

SOURCE: TRC, 1983

TABLE 3-12
MAXIMUM CONCENTRATIONS OF CONTAMINANTS IN GROUNDWATER NEAR THE ACTIVE LANDFILL
(ORGANICS IN ppb AND METALS IN ppm)

	Upgradient Wells			Downgradient Wells			
Compound	0101/ 0101A	0102/ 0102A	0122	0105/ 0105A	0104/ 0104A	0107	0123
Chloroform					(80)		
Trichloroethene				17	270(80)		
Tetrachloroethene				30	190(140)		
Benzene				11	190(140)		
Toluene				81			
Ethylbenzene				17	(4)		
Chlorobenzene				93	190(140)		
1,2-Dichlorobenzene		5.1					
Nitrobenzene		19			160(73)		

See footnotes at end of table.

TABLE 3-12 (CONT'D)
MAXIMUM CONCENTRATIONS OF CONTAMINANTS IN GROUNDWATER NEAR THE ACTIVE LANDFILL
(ORGANICS IN ppb AND METALS IN ppm)

	Upgradient Wells				Downgradient Wells		
Compound	0101/ 0101A	0102/ 0102A	0122	0105/ 0105A	0104/ 0104A	0107	0123
Naphthalene					NA	10	
Arsenic				(0.01)			
Chromium				(0.02)	(0.025)	(0.06)	
Copper	(0.02)	(0.02)	(0.04)	(0.05)	(0.05)	(1.1)	(0.5)
Iron	(1.5)	(1.1)	(2.8)	(1.9)	(26)	(0.54)	(12)
Lead	(0.023)	(0.03)		(0.43)		(0.30)	
Lithium							
Mercury		(0.006)		(0.0006)	(0.0006)	(0.009)	
Zinc	(0.26)	(0.8)	(0.16)	(2.3)			(0.18)

Blank Space - analyzed for but not detected.

NA - Not analyzed for.

( ) - Analytical data obtained by Ciba-Geigy contractor prior to 1983.

A concentration without ( ) refers to data obtained by AWARE Inc. by September 1985.

Additional sampling and analyses were conducted by AWARE in September 1985. Three upgradient wells (0101, 0102, 0122) and four downgradient wells (0104A, 0105, 0107 and 0123) were sampled. Only well 0102 exhibited organic contaminants upgradient from the landfill. Two benzene-series compounds were detected at concentrations less than 10 ug/L. Wells 0105 and 0104A contained benzene and various chlorinated aliphatic and aromatic compounds at concentrations ranging from 11 to 270 ug/L.

Groundwater quality as influenced by the Active Landfill is perhaps most accurately defined by examining the well data for lithium. Quarterly and annual analyses of wells 0102, 0105, 0107, 0122, and 0123 have been submitted to NJDEP. Lithium was not detected in any of these wells from November 1977 to May 1980, suggesting that leachate had not penetrated the secondary liner at that time.

Currently available results of groundwater monitoring in the vicinity of the Active Landfill fail to conclusively attribute the contaminated groundwater to the Active Landfill. The position of this disposal area between the Closed Chemical Landfill areas and the Filtercake Disposal Area indicate the potential for multiple point sources. The Active Landfill is currently permitted and regulated by the NJDEP Bureau of Solid Waste Administration. Therefore, source control measures as governed by CERCLA will not be considered for this disposal area.

3.3.7 Former Calcium Sulfate Disposal Area

This former disposal area was utilized in the mid-1960s as a repository for calcium sulfate sludge. Located east of the Production Area, the site consisted of a 75-foot square pit excavated to a depth of 10 feet. It is presently covered with soil. Insufficient information currently exists to assess the impact of the Former Calcium Sulfate Disposal Area on surrounding environmental media, and therefore further investigation is necessary.

3.3.8 Production Area

The Production Area is the actual industrial facility on site where manufacturing takes place. This area has grown in proportion to the increase of plant production. Located within the Production Area are several tank and drum storage areas. Up to 1980, inspection reports indicated a lack of spill prevention controls in some drum storage areas (Trautman, 1984). By 1982 however, many of these areas did contain such controls.

Soil sampling by NUS Corporation Region 2 FIT did not indicate any significant surface contamination within the Production Area. Wells surrounding the Production Area (Table 3-13) do indicate contaminants being released in the south Production Area; however, contaminants found south and east of the Production Area may be influenced by contamination from the wastewater treatment plant and the northernmost contamination plume, respectively. No information is currently available on the condition of potential point sources in the Production Area. Therefore, it will not be further considered until more investigative work to pinpoint sources is completed.

3.3.9 Compactor Area

The Compactor Area is an inactive disposal area located approximately 250 feet north of the Production Area. Nonhazardous plant refuse, predominantly construction debris, was reportedly compacted here beginning in 1975. There is the possibility, however, that packaging material containing residual wastes may have been disposed of in this area (Baker, 1985). There are no available analytical data concerning the compacted materials. Geophysical surveys conducted during the RI indicate that the Compactor Area is essentially clean with regard to contaminated groundwater. However, the absence of groundwater and soil data in the vicinity of the Compactor Area precludes its assessment as a contaminant source. As a result, further investigation is necessary in order to eliminate the area as a contaminant source or to consider the area for remedial action.

TABLE 3-13
MAXIMUM CONTAMINANT CONCENTRATIONS FOUND IN WELLS IN THE PLANT PRODUCTION AREA
(ORGANICS IN ppb AND METALS IN ppm)

Compound	Northwest of Production Area				Middle of Production Area		South of Production Area			East of Production Area	
	RI-27S	RI-27D	1106	1107	0183	0184	0132	1102	1103	1104	1105
Total xylenes										15000	
Tetrachloroethene			10								
Methylene chloride	38										
Trichloroethene							1200				
1,1,1-Trichloroethene							60				
1,2-Dichloroethene							22				
1,2-Dichlorobenzene					1.3		380			11	190
Naphthalene							3.1				
Nitrobenzene					510		160				
Chlorobenzene											
Benzene											

See footnotes at end of table.

TABLE 3-13 (CONT'D)
MAXIMUM CONTAMINANT CONCENTRATIONS FOUND IN WELLS IN THE PLANT PRODUCTION AREA
(ORGANICS IN ppb AND METALS IN ppm)

	Northwest of Production Area				Middle of Production Area		South of Production Area			East of Production Area	
ompound	RI-27S	RI-27D	1106	1107	0183	0184	0132	1102	1103	1104	1105
rans-1,2-Dichloroethene											
hromium	0.043										
opper	0.025	0.023						0.110	0.290		
on	76.7	10.3									
ead	0.036	0.013									
langanese	0.156	0.058									
lercury	0.0009	0.0003									
lickel			0.056	0.058				0.067			
inc	0.089	0.087									
admium									0.011		

lank Space - analyzed for but not detected.

) - Analytical data obtained by Ciba-Geigy contractor prior to 1983.

A concentration without ( ) refers to data obtained by AWARE Inc. by September 1985.

3.3.10 Former Fire Prevention Training Area

This inactive training area is located adjacent to the Toms River immediately south of the cooling water intake facility. Oils and solvents were reportedly burned in kettles in this area for fire prevention exercises (AWARE, 1986). The presence of contaminants in nearby well RI-7, which is screened in the Upper Cohansey, indicates the possibility for this source area to be contributing to groundwater contamination. However, the presence of a major plume in this area and the previous implication of a Production Area source make it difficult to directly separate out the contaminant contribution from this site. As a result, source control remedial action will not be considered at this time, as further investigations in the form of surface and subsurface soil sampling would be necessary to characterize the site.

3.3.11 Borrow Area

The Borrow Area is a large site north of the Production Area and has been a source of fill and a place for piling construction debris resulting from plant activities. This area is being reviewed due to the presence of drums and unknown debris identified in past aerial photographs. Current sources of information for this area are limited to past geophysical surveys, aerial photographs, and surface soil sampling conducted by NUS Corporation Region 2 FIT.

Aerial photographs taken in 1956 show the first evidence of activity in the Borrow Area. Two separate areas are noted. The first area is north of the eastern half of the Producton Area and contains debris. The second area is southwest of the aforementioned area and consists of an access road leading from the western half of the Production Area to a pit (EPIC, 1984). Ground Penetrating Radar (Weston Geophysical, 1986) confirmed the presence of this pit, which is now filled in, and also indicates the existence of point targets (drums or construction debris) within this pit. By 1962 photographs show that the Borrow Area had greatly extended in size so as to include the original sites mentioned above in one large area. A large trench existed and the outline of the debris noted in 1956 was still evident. In addition, drums were stored in this area, and the old pit area was filled in. By 1965 the large trench was filled in but debris and containers were still evident. In 1976 a large quantity of drums were stored in the Borrow Area, but most excavation and fill operations had ceased with vegetation again reclaiming most of the area.

Past history has produced a concern over the possibility of waste dumping or burial in this area. Surface soil sampling reveals the presence of polycyclic aromatic hydrocarbons in excess of State soil cleanup standards, but does not conclusively indicate any chemical dumping. However, most compounds such as solvents or aromatic hydrocarbons would have most likely migrated down through the sandy soil or volatilized long before sampling was conducted. Subsurface soil sampling would be necessary for detecting buried waste or vertical contaminant migration. Electromagnetic surveys also indicate that groundwater contamination does not appear evident (Weston Geophysical, 1986), though well placement and sampling would be necessary to obtain definite conclusions.

As a result, past practices in this area raise concern, but current data are inconclusive. Therefore, subsurface soil sampling and well placement and sampling would be required before the area can be addressed for remedial action.

3.3.12 Suspected East Overflow Area

The Suspected East Overflow Area parallels the pipeline which carried wastewater from the wastewater treatment plant to the backfilled lagoons (Figure 3-1). This area first appears as a light-toned "possible" impoundment in aerial photographs from 1976 (EPIC, 1984). This area still existed in 1983 photographs but has since been filled in. A water monitoring report completed in 1976 (EPA, 1976) did not allude to the existence of this area as part of the treatment system; the area, therefore, has an unknown use.

Surface soil sampling conducted by NUS Region 2 FIT has detected polycyclic aromatic hydrocarbons but otherwise has been inconclusive in defining the purpose and presence of waste (if any) in this area. If waste does exist, it is buried and would require further subsurface soil sampling. Therefore, the need for remedial action of this area cannot be addressed at this time.

3.3.13 Casual Dumping Area

The Casual Dumping Area was one of the earliest known waste areas according to historic aerial photographs (EPIC, 1984). It initally existed as a single road abruptly terminating in the woods south of the Production Area. By 1957 several roads crossed this area connecting the southwest boundary of the Production Area with the west boundary of the Wastewater Treatment Plant Area. Also, an independent road ran south from the western corner of the Production Area into the woods where it ended. By 1962 the road network included a clearing where ground staining was evident. In addition, the independent road noted in 1956 had a trench paralleling its eastern edge and a clearing at its southern terminus where ground staining was again evident. By 1976 the Production Area grew to encompass the road network, and the second independent road appears to have fallen from use and is beginning to be overgrown.

Surface soil sampling was inconclusive. Any waste that may have been dumped or deposited would have long since volatilized, migrated to groundwater, or been buried. Ground Penetating Radar has detected the presence of disturbed soil and point source reflectors which may indicate the existence of a pit with buried drums or similar waste. Groundwater in the southern section of the Production Area (which has now encompassed the Casual Dumping Area) is contaminated as shown in Table 3-12. However, it is not known if this contamination is from the Dumping Area or from more recent facilities located in the expanded Production Area. Finally, deteriorated drums and their contents are exposed in some areas on the ground surface.

In conclusion, the Casual Dumping Area may be a contaminant source, but no conclusions can be made without subsurface borings and the placement of wells at the source. As a result, further investigation is required before the need for remedial action is determined.

3.4 Conclusions

Based on the above source area reviews, the following known or potential contaminant sources are not being retained for remedial action measures due to the applicability of a primary regulation other than CERCLA/SARA:

- Wastewater Treatment Plant Area
- Active Landfill

The following areas are of concern but require further investigation before remedial action alternatives are considered:

- Lime Sludge Disposal Area
- Former Calcium Sulfate Disposal Area
- Production Area
- Compactor Area
- Former Fire Prevention Training Area
- Borrow Area
- Suspected East Overflow Area
- Casual Dumping Area

The remaining areas shown below will be retained for review of remedial actions in the forthcoming feasibility study:

- Backfilled Lagoons
- Drum Disposal Area
- Filtercake Disposal Area

4

4.0 HYDROGEOLOGICAL INVESTIGATION

The objectives of the hydrogeological investigation conducted at the Ciba-Geigy Site were

- Comprehensive description of site stratigraphy to provide a sound geological framework for groundwater modeling.
- Installation of a well array that, together with previously installed wells, would provide the means to define the distribution of contaminated groundwater and determine groundwater flow patterns.
- Characterization of contaminant source areas and their impact on the groundwater system.
- Generation of adequate data for the recommendation of remedial measures.

Section 4.1 provides a summary of the regional geology and hydrogeology. Sections 4.2 through 4.5 provide the descriptions and results of interdependent geological, hydrogeological, and groundwater contamination studies performed at the Ciba-Geigy Site. Section 4.6 presents the conclusions of the hydrogeologic investigation and recommended additional studies.

4.1 Geologic and Hydrogeologic Setting

Geologic relationships and the hydrogeologic characteristics of shallow formations in this section of the New Jersey Coastal Plain are abundantly documented and well understood. They constitute a frame of reference within which hydrogeologic studies were conducted at the Ciba-Geigy Site. The regional geology and hydrogeology are briefly discussed in Section 4.1.1. Section 4.1.2 presents the site geologic and hydrogeologic setting. Local aquifer development is discussed in Section 4.1.3.

4.1.1 Regional Geology and Hydrogeology

Regional geologic relationships and hydrogeologic characteristics of unconsolidated sediments in the New Jersey Coastal Plain are described in numerous documents (Zapecza 1984, Carter 1978, Isphording and Lodding 1969, Rhodehamel 1973, Fisher 1961, Klein 1967, Richards et al. 1962, Perry et al. 1975). Zapecza (1984) has summarized these investigations stating that the New Jersey Coastal Plain is a seaward-dipping wedge of unconsolidated sediments ranging in age from Cretaceous to Holocene (Table 4-1; Figures 4-1, 4-2). The Cretaceous and Tertiary sediments generally strike northeast-southwest and dip gently southeast at 10-60 ft/mile, whereas overlying Quaternary sediments are generally flat lying.

Zapecza (1984) divides the depositional history of Cretaceous and Tertiary sediments into nine aquifer systems and six major confining units. The aquifer systems include

- Lower, middle, and upper aquifers of the Potomac-Raritan Magothy aquifer system
- Englishtown aquifer system
- Wenonah - Mount Laurel aquifer
- Vincentown aquifer
- Piney Point aquifer
- Atlantic City 800-foot sand
- Kirkwood - Cohansey aquifer system

These sediments are generally coarsening upward sequences believed to have been deposited in inner shelf, near shore, and beach areas during marine regressions.

The six confining units include

- The confining bed between the lower and middle aquifer of the Potomac-Raritan-Magothy aquifer system.
- The confining bed between the middle and upper aquifers of the Potomac-Raritan-Magothy aquifer system.
- Merchantville-Woodbury confining bed.

TABLE 4-1

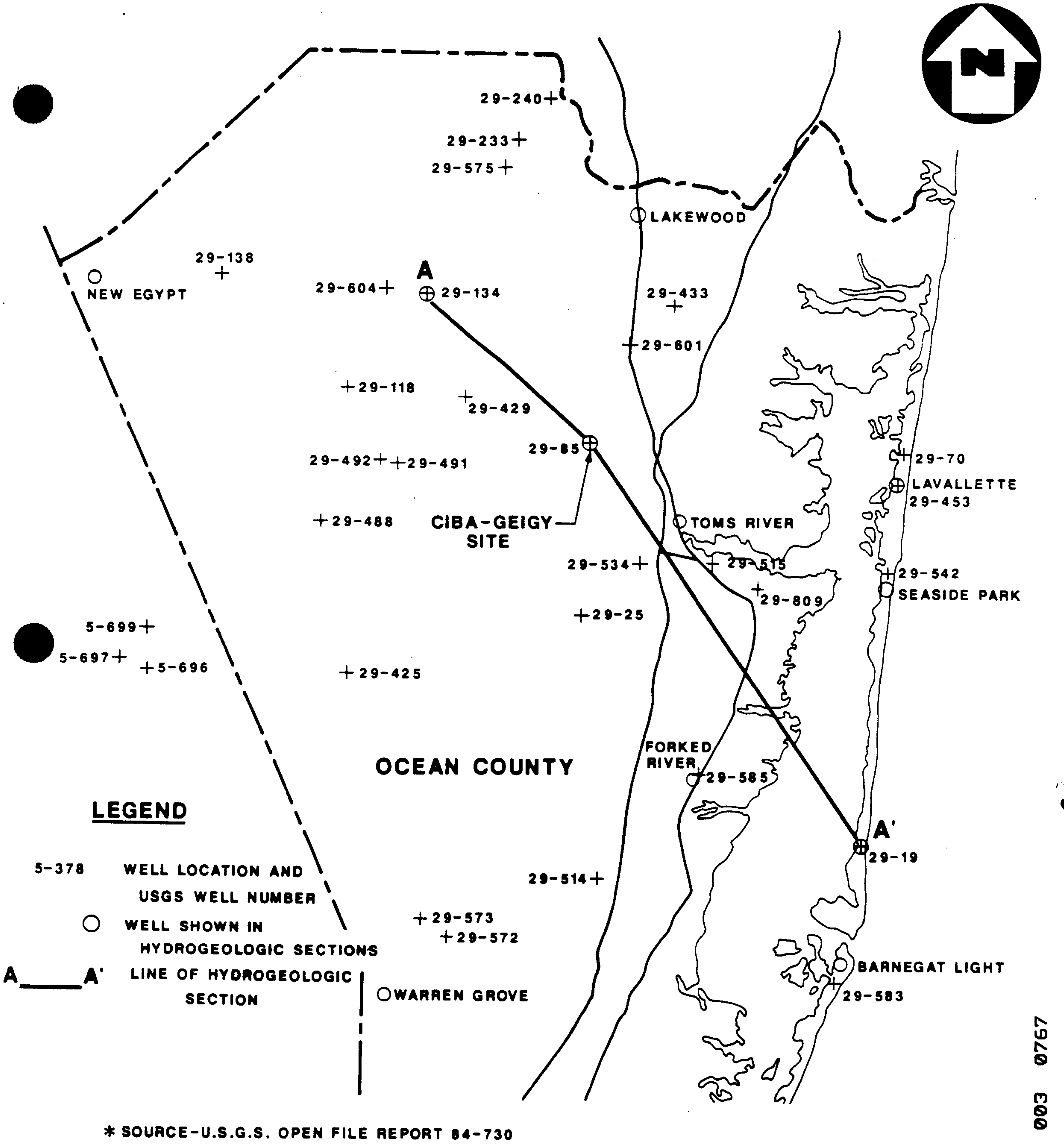
GEOLOGIC AND HYDROGEOLOGIC UNITS OF THE NEW JERSEY COASTAL PLAIN

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		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.
		Beacon Hill Gravel	Gravel, quartz, light colored, sandy.			
		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		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.
				Rio Grande w-bz[1]		
				confining bed		
				Atlantic City 800-foot sand		A major aquifer along the coast.
	Eocene	Piney Point Formation	Sand, quartz and glauconite, fine- to coarse-grained.	Composite confining bed		Alloway clay member or equivalent
					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.			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.		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.			Poorly permeable sediments.
Cretaceous	Upper Cretaceous	Tinton Sand	Sand, quartz, and glauconite, brown and gray, fine- to coarse-grained, clayey, micaceous.			
		Red Bank Sand			Red Bank sand[2]	Yields small quantities of water in and near its outcrop area.
		Navesink Formation	Sand, clayey, silty, glauconitic, green and black, medium- to coarse-grained.			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 subsurface, 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 Zapecza, 1984, table 2

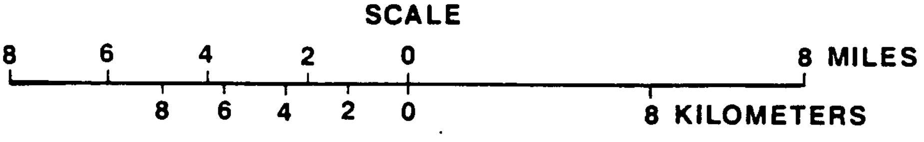


* SOURCE-U.S.G.S. OPEN FILE REPORT 84-730

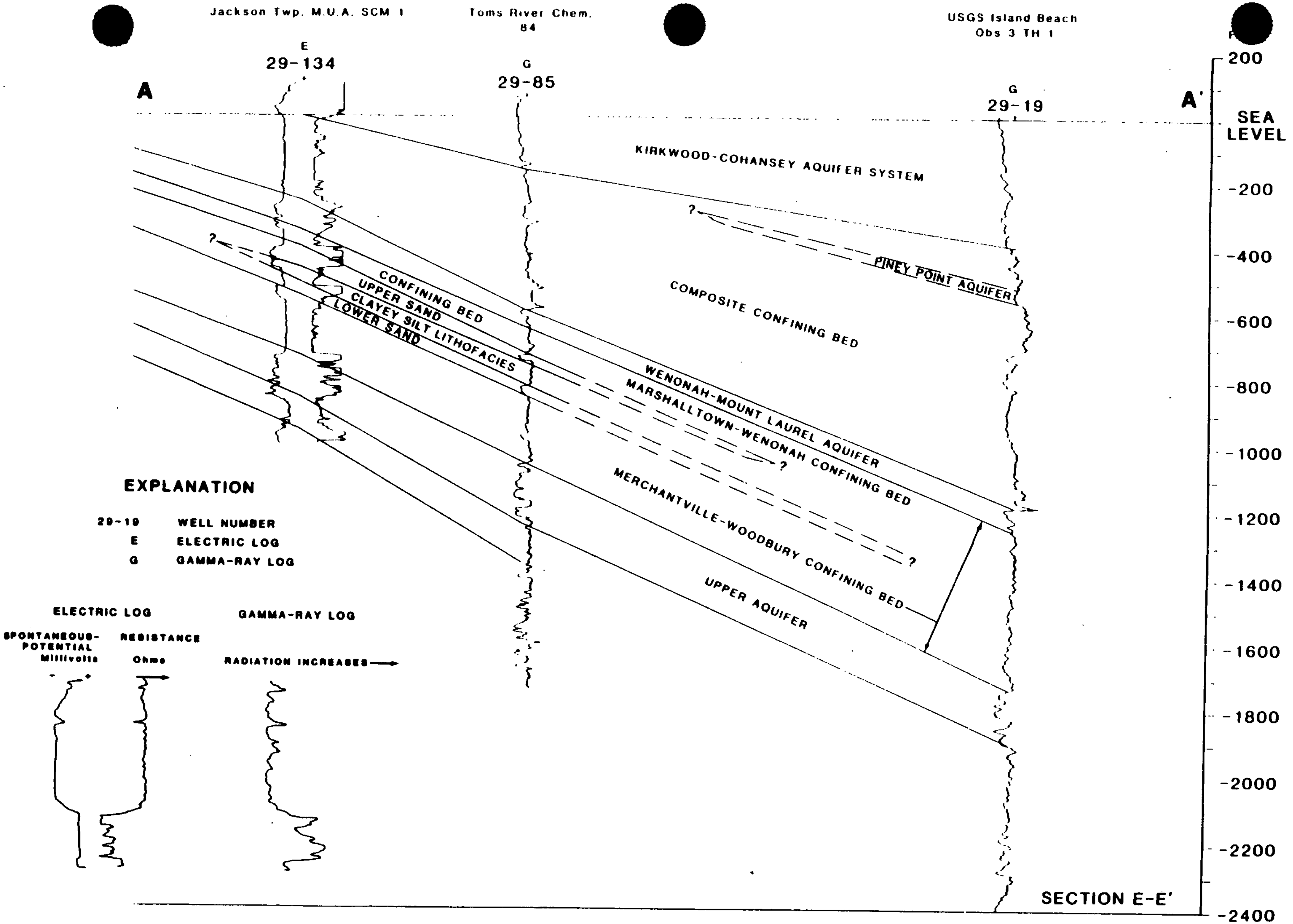
SS SECTION LINE THROUGH THE NEW JERSEY COASTAL PLAIN

(SEE CROSS SECTION ON FIGURE 4-2)

FIGURE 4-1



NUS CORPORATION



REGIONAL STRATIGRAPHIC RELATIONSHIPS, CIBA-GEIGY, DOVER TWP., N.J.

FIGURE 4-2

Adapted from U.S.G.S. Open File Report 84-730, Plate 3.¹

NUS CORPORATION

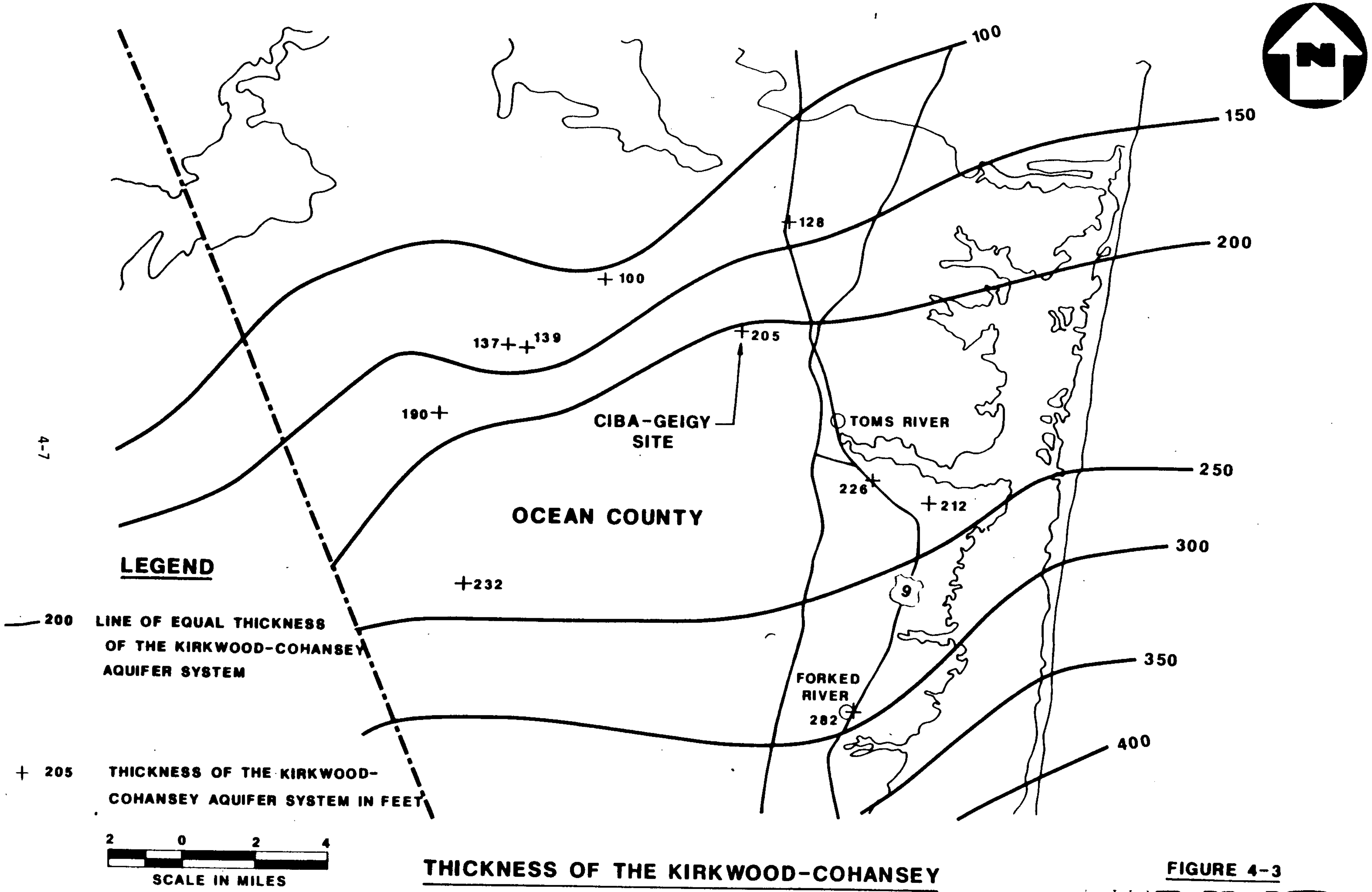
- Marshalltown-Wenonah confining bed.
- Composite confining bed separating the Vincentown, Red Bank Sand, Piney Point, and Atlantic City 800-foot sand aquifers.
- The confining bed between the Atlantic City 800-foot sand and the Kirkwood-Cohansey aquifer system.

The last four of these sequences are characterized by the presence of heavy concentrations of glauconite in association with very fine-grained sediments, and are interpreted to have been deposited during marine transgressions.

4.1.2 Site Geologic and Hydrogeologic Setting

The Ciba-Geigy Site is directly underlain by the Kirkwood Formation and Cohansey Sand. Regionally, these Miocene age units are the principal elements of the Kirkwood-Cohansey aquifer system. In some areas, overlying deposits of the Beacon Hill Gravel and Bridgeton Formation are components of the Kirkwood-Cohansey aquifer system, but these units are not present at the site (Zapecza, 1984). In general, the Kirkwood Formation is composed of quartz-bearing very fine- to medium-grained sand and may contain dark-colored micaceous, diatomaceous clay, known to be regionally extensive at the base of the formation. The Cohansey Sand is composed of light-colored, medium- to coarse-grained quartz sand with pebbles, and locally, clay beds (Seaber 1965, Rhodehamel 1973). The contact between the Cohansey Sand and the uppermost member of the Kirkwood Formation is gradational (Isphording and Lodding 1969, Carter 1978) and has been interpreted by Isphording and Lodding (1969) to represent a change in depositional environments from "moderate depth to shallow water". The thickness of the Kirkwood-Cohansey aquifer system in the vicinity of the Ciba-Geigy Site is approximately 205 feet (Figure 4-3). Perched water tables and semiconfined aquifer conditions occur locally within the Kirkwood-Cohansey aquifer system.

Transmissivity estimates for Kirkwood-Cohansey aquifer system range from 11,000 gpd/ft to 107,000 gpd/ft (Groundwater Management Planning, 1978).



THICKNESS OF THE KIRKWOOD-COHANSEY AQUIFER SYSTEM, NEW JERSEY

FIGURE 4-3

* SOURCE-U.S.G.S. OPEN FILE REPORT 84-730

NUS CORPORATION

The water table aquifer in Ocean County, which includes part of the Kirkwood Formation and the overlying sediments, primarily the Cohansey Sand, has hydraulic conductivities ranging from 105 to 4363 gpd/ft^2 (5.0×10^{-3} to 2.1×10^{-1} cm/sec). Transmissivity varies greatly with saturated thickness. The variable nature of the sediments in the Kirkwood-Cohansey aquifer county-wide indicates that averaged values may not necessarily be representative of the site aquifer conditions. A detailed discussion of site aquifer testing is presented in Section 4.3.

4.1.3 Groundwater Use

The Kirkwood-Cohansey aquifer system in the area surrounding the Ciba-Geigy Site is tapped by municipal, industrial, and private wells. The 7.7 million gallons of groundwater from the Kirkwood-Cohansey aquifer system represents approximately 44 percent of all groundwater pumped in Ocean County during 1976 (Figure 4-4). Of this total, 2.7 million gallons were pumped by the Toms River Water Company and the Ciba-Geigy Toms River Chemical Plant (Table 4-2).

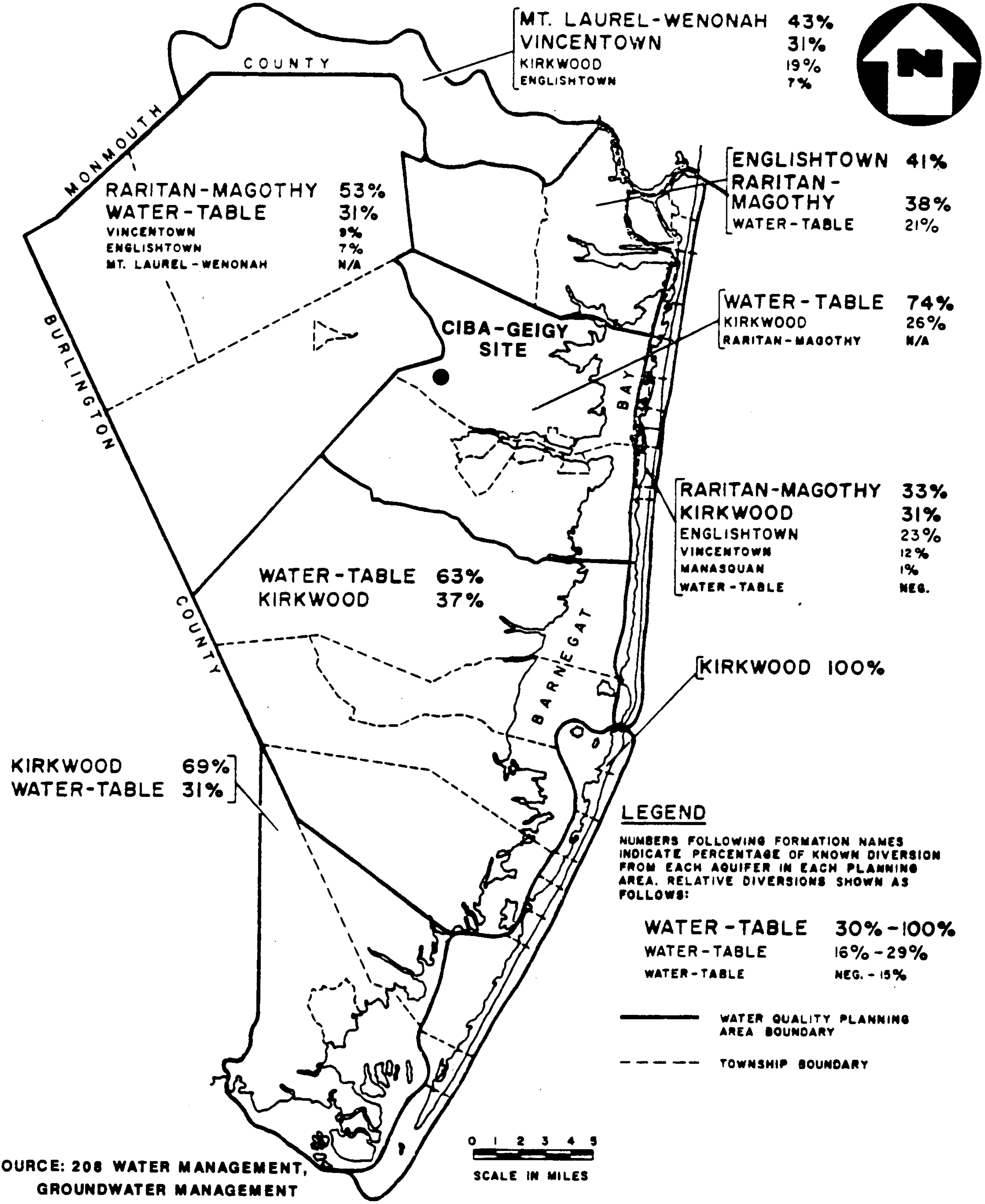
The nearest public water supply well, TRWC 20, is located approximately 2200 feet from the site boundary on the east side of the Toms River (Plate 1). Residential wells near the site are concentrated along the southwestern site boundary, and along Cardinal Drive between the eastern site boundary and the Toms River (Figure 4-5). Additional residential wells are located along Coulter Street between well TRWC 20 and the Toms River.

A discussion of local groundwater quality is presented in Section 4.5.

4.2 Site Lithology

The objectives of the Lithologic Investigation are as follows:

- To determine the lithology and stratigraphy at the site.
- To establish 59 additional sampling points distributed along the Toms River and around the plant border area.



SOURCE: 208 WATER MANAGEMENT,
GROUNDWATER MANAGEMENT
OCEAN COUNTY, NEW JERSEY. 1978

FIGURE 4-4

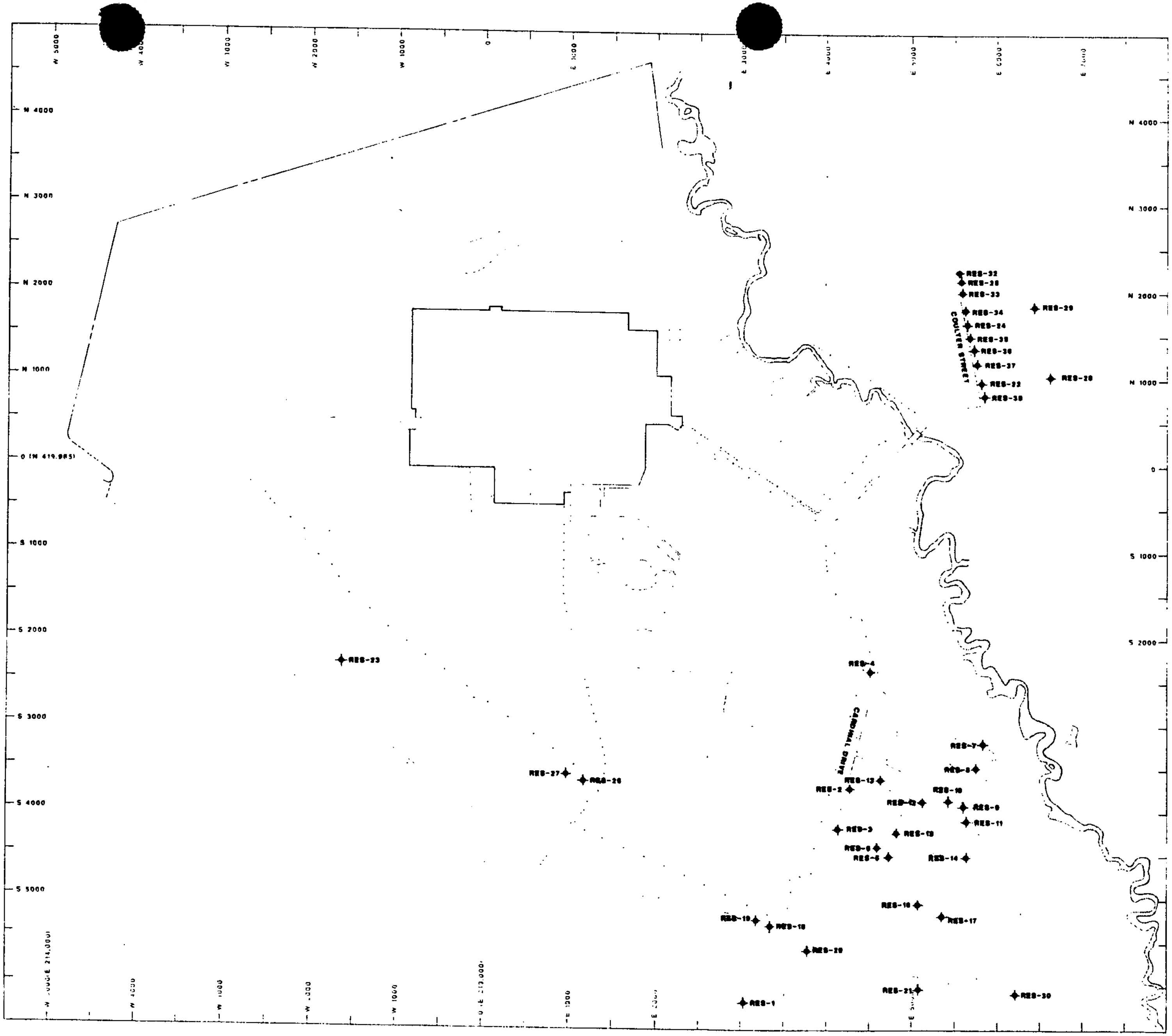
OCEAN COUNTY AQUIFER UTILIZATION BY WATER QUALITY PLANNING AREA, 1976

NUS CORPORATION

TABLE 4-2
DATA FOR MAJOR WELLS AT OR IN THE VICINITY OF CIBA-GEIGY

Well Owner	Well No. or Name	Depth (ft)*	Diameter (in.)	Screen Setting (ft/ft)*	Yield (gpm)	Specific Capacity (gpm/ft)	Static/ Pumping Level (ft)*	Date Meas. (Mo./Yr.)	Status
Ciba-Geigy Toms River Plant	100A	105	16	83/103	215	6.3	45/79	9/77	Active
	200A	105	16	82/102	310	9.1	47/81	9/77	Active
	220	97	12	82/97	340	9.2	44/81	9/77	Active
	400	98	12	83/98	575	16.9	45/79	9/77	Active
	404	97	12	82/97	320	13.3	46/70	9/77	Active
	502	88	12	73/88	365	13.0	36/64	9/77	Active
	503	110	12	85/110	480	13.7	41/76	9/77	Active
	504	93	12	78/93	340	7.1	28/76	9/77	Active
Toms River W.C.	14	66	12	40/--	50	--	--	--	Active
	15	227	10	195/225	703	22.0	8/40	--	Active
	16	228	12	196/226	805	--	-/171	6/63	Active
	17	59	12	45/55	715	28.6	2/27	1/66	Active
	18	59	12	47/57	737	36.9	7/27	5/65	Active
	19	62	12	50/60	602	19.4	12/43	6/67	Active
	20	92	12	67/87	503	12/6	19/59	6/66	Active
	21	58	12	45/55	805	24.4	11/44	5/68	Active
	22	126	12	106/126	700	22.9	60/90	2/77	Active
	23	275	12	254/274	300	3.1	70/166	2/77	Active
	24	283	12	--	520	15.3	57/91	4/77	Active
	25	283	12	243/--	450	3.7	85/215	3/77	Active
	26	133	12	113/133	700	16.1	64/95	5/76	Active
	27	291	12	250/--	550	3.2	65/235	7/76	Active
	28	125	12	105/125	704	19.6	62/98	5/75	Active
	29	135	12	115/135	726	21.4	64/98	5/75	Active

Values Rounded to Nearest Foot
Source: Groundwater Management Planning, 1978.



RESIDENTIAL WELL LOCATION MAP

LEGEND

- RAILROAD SPUR
- SURVEYED BOUNDARY
- BOUNDARY FENCE
- BOUNDARY ROAD
- ✦ RESIDENTIAL WELL

* WELL LOCATIONS MAY NOT BE EXACT DUE TO SCALE

FIGURE 4-5

NUS CORPORATION

- To gather data to be used for groundwater modeling.

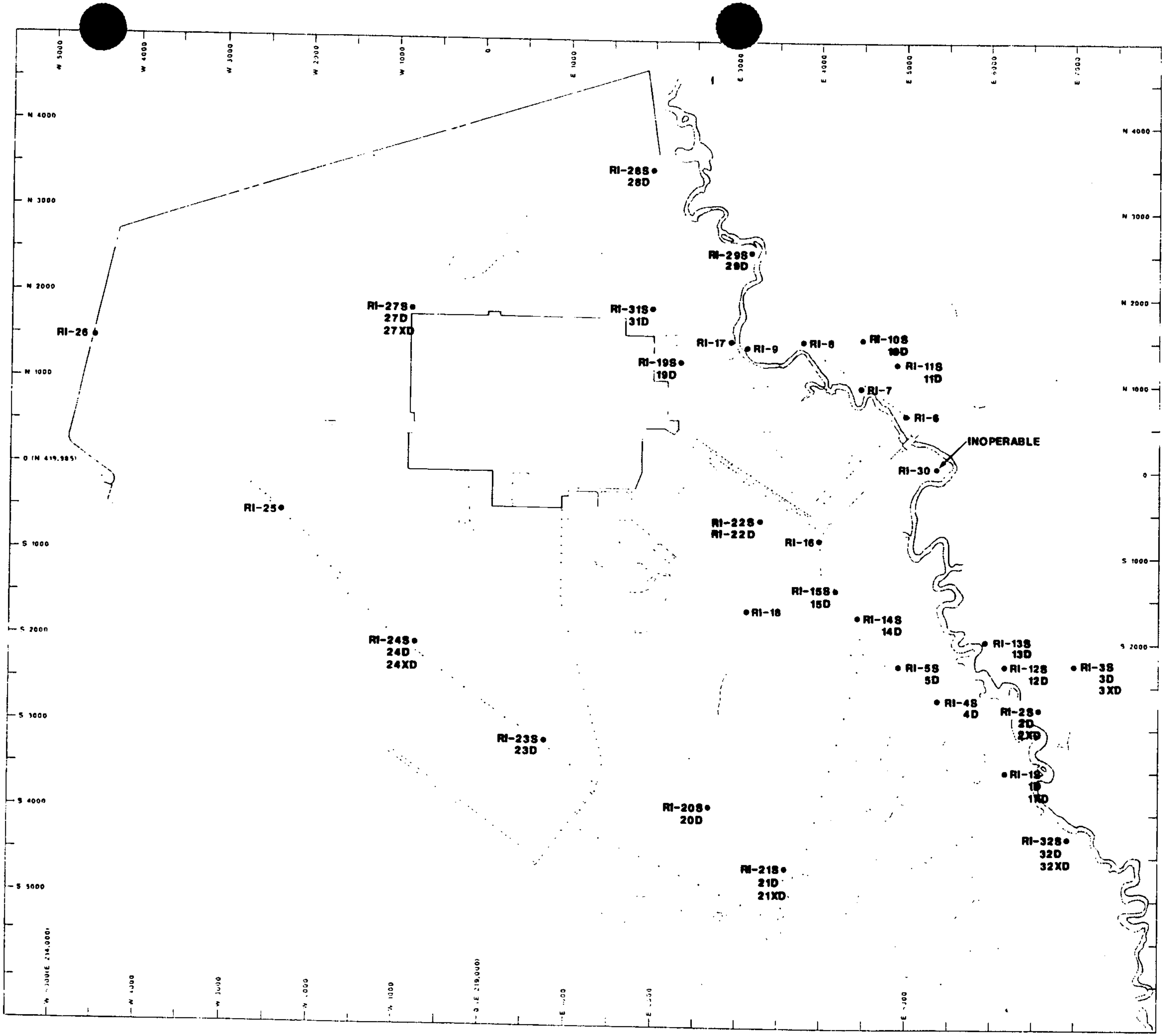
This section describes the methods and results of lithologic investigations performed at the Ciba-Geigy Site by NUS Corporation. Section 4.2.1 discusses the drilling program and borehole geophysical methods. Section 4.2.2 presents the results of the lithologic investigations.

4.2.1 Methods of Lithologic Investigation

Fifty-nine 4-inch monitoring wells at 32 different locations were installed by NUS Corporation for the EPA during this Remedial Investigation (Figure 4-6). All EPA monitoring wells are distinguished on figures, tables, plates, and text by the "RI-" prefix. Well depths, and screen elevations of these wells are summarized in Table 4-3 and Appendix D-2. Detailed well construction information, well logs, and a well construction diagram for each well are provided in Appendices D-8 and D-9. The geology at the Ciba-Geigy Site was determined mainly on the basis of split-spoon sampling conducted at the 32 EPA monitoring well locations. These wells were installed between April and October 1985.

In addition to wells installed by NUS Corporation for EPA, NUS also used well logs from many existing piezometers, monitoring wells, purge wells, production wells, and off-site wells that are present at the Ciba-Geigy Site and surrounding area (Figures 4-6, 4-7, 4-8, 4-9, and Plate 1). Well log quality varies greatly because they were recorded by a number of different contractors and some contain insufficient information (Appendices D-10, D-11).

NUS/EPA
WELL CLUSTER LOCATION MAP



LEGEND

- RAILROAD SPUR
- SURVEYED BOUNDARY
- BOUNDARY FENCE
- BOUNDARY ROAD
- ●RI-21 EPA MONITORING WELL

* WELL LOCATION MAY NOT BE EXACT DUE TO SCALE.

FIGURE 4-6

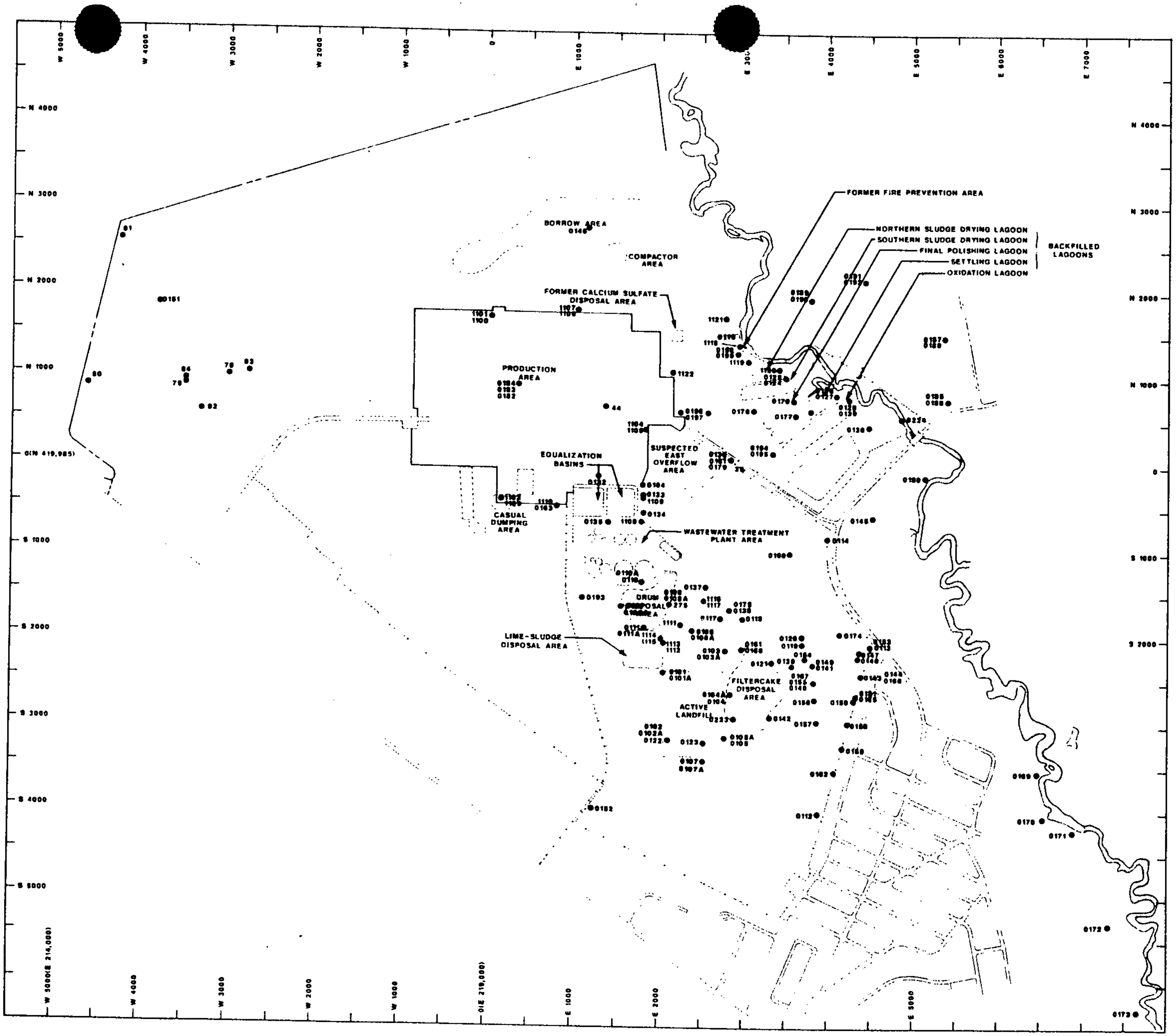
NUS CORPORATION

TABLE 4-3
SCREEN SETTINGS OF WELLS INSTALLED DURING THE REMEDIAL INVESTIGATION

Well No.	Screen Depth (ft)		Screen Elev. (ft)	
	Top	Bottom	Top	Bottom
RI-1S	14.00	20.00	8.80	2.80
RI-1D	24.00	34.00	-0.80	-10.80
RI-1XD	54.00	65.00	-31.30	-42.30
RI-2S	3.00	9.00	11.08	5.08
RI-2D	9.50	14.50	4.71	-0.29
RI-2XD	39.00	50.00	-24.71	-35.71
RI-3S	25.60	31.70	-5.48	-11.58
RI-3D	38.50	49.50	-18.29	-29.29
RI-3XD	165.50	171.50	-145.38	-151.38
RI-4S	34.00	45.00	15.10	4.10
RI-4D	68.75	79.75	-19.34	-30.35
RI-5S	23.88	34.88	16.07	5.07
RI-5D	53.25	64.25	-13.40	-24.40
RI-6	28.75	34.75	-5.53	-11.53
RI-7	23.00	29.00	-4.24	-10.24
RI-8	25.50	31.50	-3.04	-9.04
RI-9	15.00	21.00	6.18	0.18
RI-10S	28.20	34.20	-5.08	-11.08
RI-10D	54.00	65.00	-35.80	-41.80
RI-11S	22.80	28.80	-1.80	-7.80
RI-11D	61.00	67.00	-39.82	-45.82
RI-12S	22.38	28.38	-5.12	-11.12
RI-12D	34.00	45.00	-16.77	-27.77
RI-13S	14.90	20.90	-1.41	-7.41
RI-13D	30.20	41.20	-16.57	-27.57
RI-14S	17.00	28.00	19.09	8.09
RI-14D	49.50	60.50	-13.41	-24.41
RI-15S	28.88	39.88	19.27	8.27
RI-15D	59.50	70.50	-10.95	-21.95

TABLE 4-3 (CONT'D)
SCREEN SETTINGS OF WELLS INSTALLED DURING THE REMEDIAL INVESTIGATION

Well No.	Screen Depth (ft)		Screen Elev. (ft)	
	Top	Bottom	Top	Bottom
RI-16	61.20	72.20	-9.80	20.80
RI-17	26.50	32.50	-3.00	-9.00
RI-18	35.58	41.58	4.22	-1.78
RI-19S	30.75	36.75	19.15	13.15
RI-19D	38.50	49.50	11.40	0.40
RI-20S	56.00	62.00	-2.03	-8.03
RI-20D	79.50	90.50	-25.43	-36.43
RI-21S	34.00	40.00	14.19	8.19
RI-21D	85.00	96.00	-36.80	-47.80
RI-21XD	202.00	208.00	-153.90	-159.90
RI-22S	40.00	46.00	15.10	9.10
RI-22D	59.00	70.00	-4.10	-15.10
RI-23S	68.00	74.00	-2.47	-8.47
RI-23D	84.50	95.50	-18.97	-29.97
RI-24S	59.00	65.00	6.59	0.59
RI-24D	74.00	85.00	-8.21	-19.21
RI-24XD	203.00	209.00	-137.21	-143.21
RI-25	44.00	55.00	7.12	-3.88
RI-26	95.00	106.00	-22.00	-33.00
RI-27S	49.00	55.00	10.80	4.80
RI-27D	89.00	100.00	-29.40	-40.40
RI-27XD	205.00	211.00	-145.10	-151.10
RI-28S	30.50	41.50	-2.00	-13.00
RI-28D	52.50	63.50	-23.70	-34.70
RI-29S	27.00	33.00	-8.20	-14.20
RI-29D	56.48	67.48	-37.68	-48.68
RI-31S	40.85	46.85	5.45	-0.55
RI-31D	78.00	89.00	-31.30	-42.30
RI-32D	53.00	64.00	-35.00	46.82
RI-32XD	168.50	174.50	-151.15	-157.15



CIBA-GEIGY MONITORING WELL LOCATION MAP

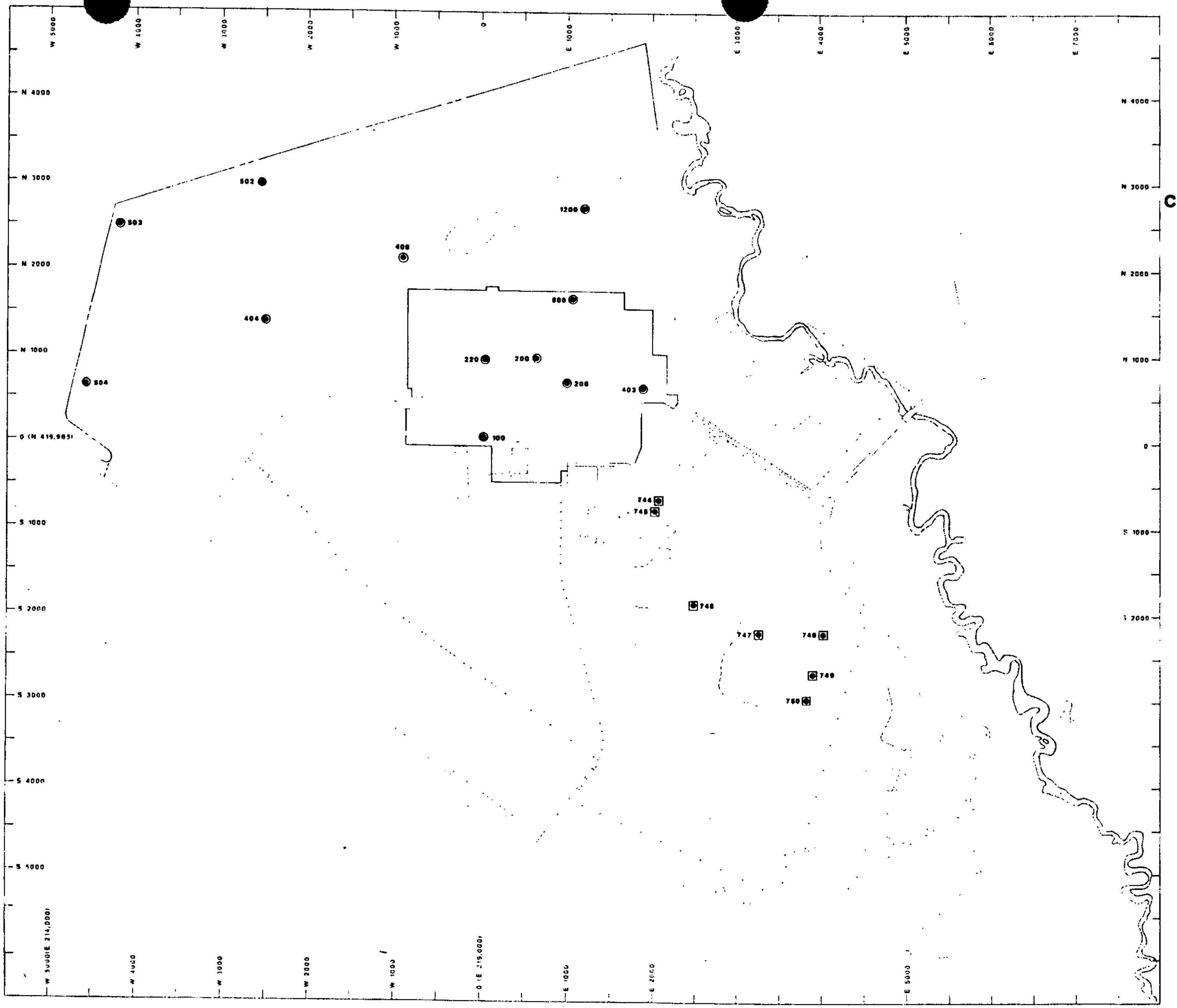
LEGEND

- RAILROAD SPUR
- SURVEYED BOUNDARY
- BOUNDARY FENCE
- BOUNDARY ROAD
- ● MONITORING WELL

* WELL LOCATIONS MAY NOT BE EXACT DUE TO SCALE

FIGURE 4-7

NUS CORPORATION



CIBA-GEIGY PURGE AND PRODUCTION WELL LOCATION MAP

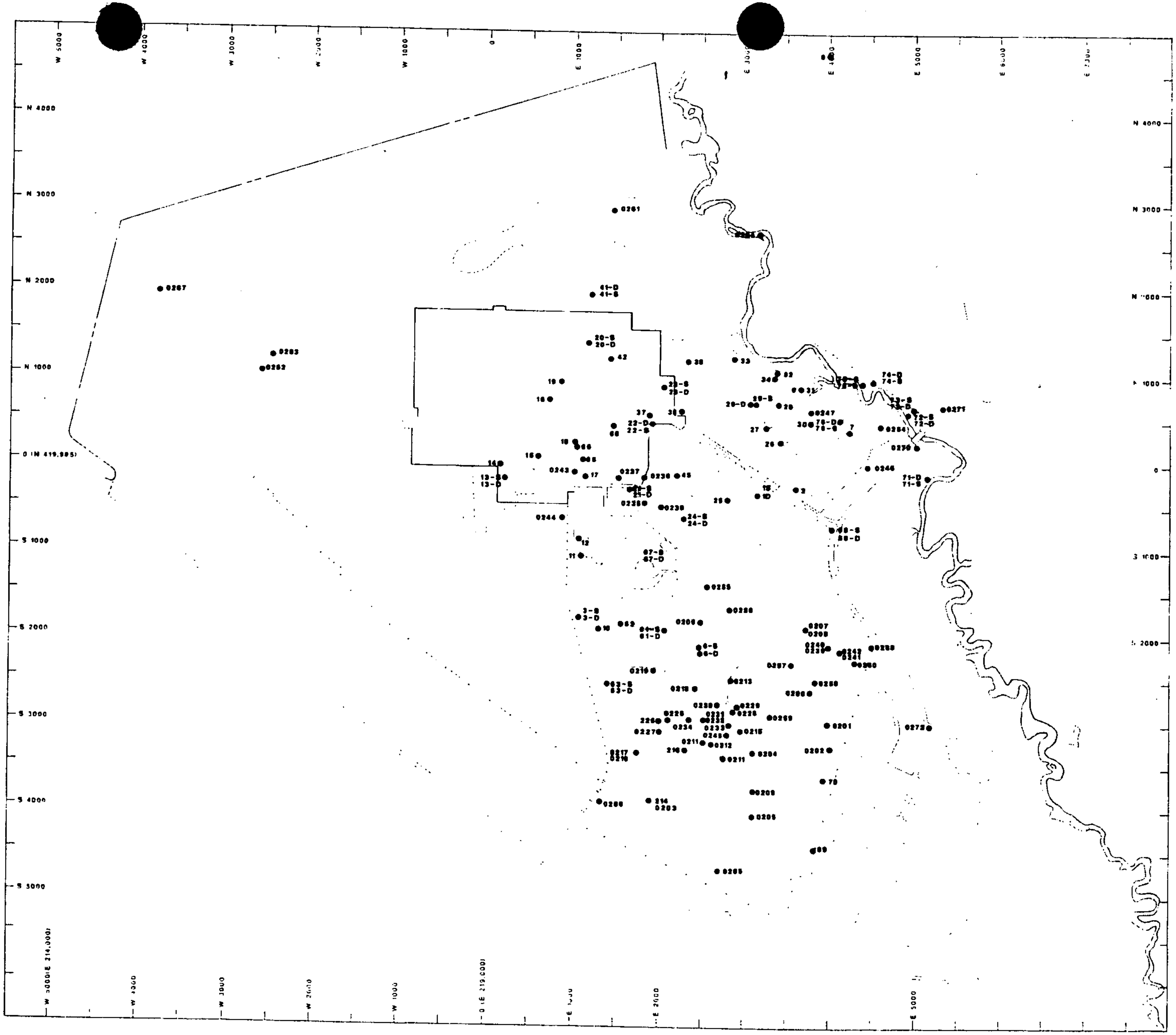
LEGEND

- RAILROAD SPUR
- SURVEYED BOUNDARY
- BOUNDARY FENCE
- BOUNDARY ROAD
- ■ PURGE WELL
- ● PRODUCTION WELL

* WELL LOCATIONS MAY NOT BE EXACT DUE TO SCALE.

FIGURE 4-8

NUS CORPORATION



CIBA-GEIGY PIEZOMETER LOCATION MAP

LEGEND

—+—+—	RAILROAD SPUR
—·—·—	SURVEYED BOUNDARY
—··—··—	BOUNDARY FENCE
-------	BOUNDARY ROAD
●	PIEZOMETER

* WELL LOCATIONS MAY NOT BE EXACT DUE TO SCALE

FIGURE 4-9

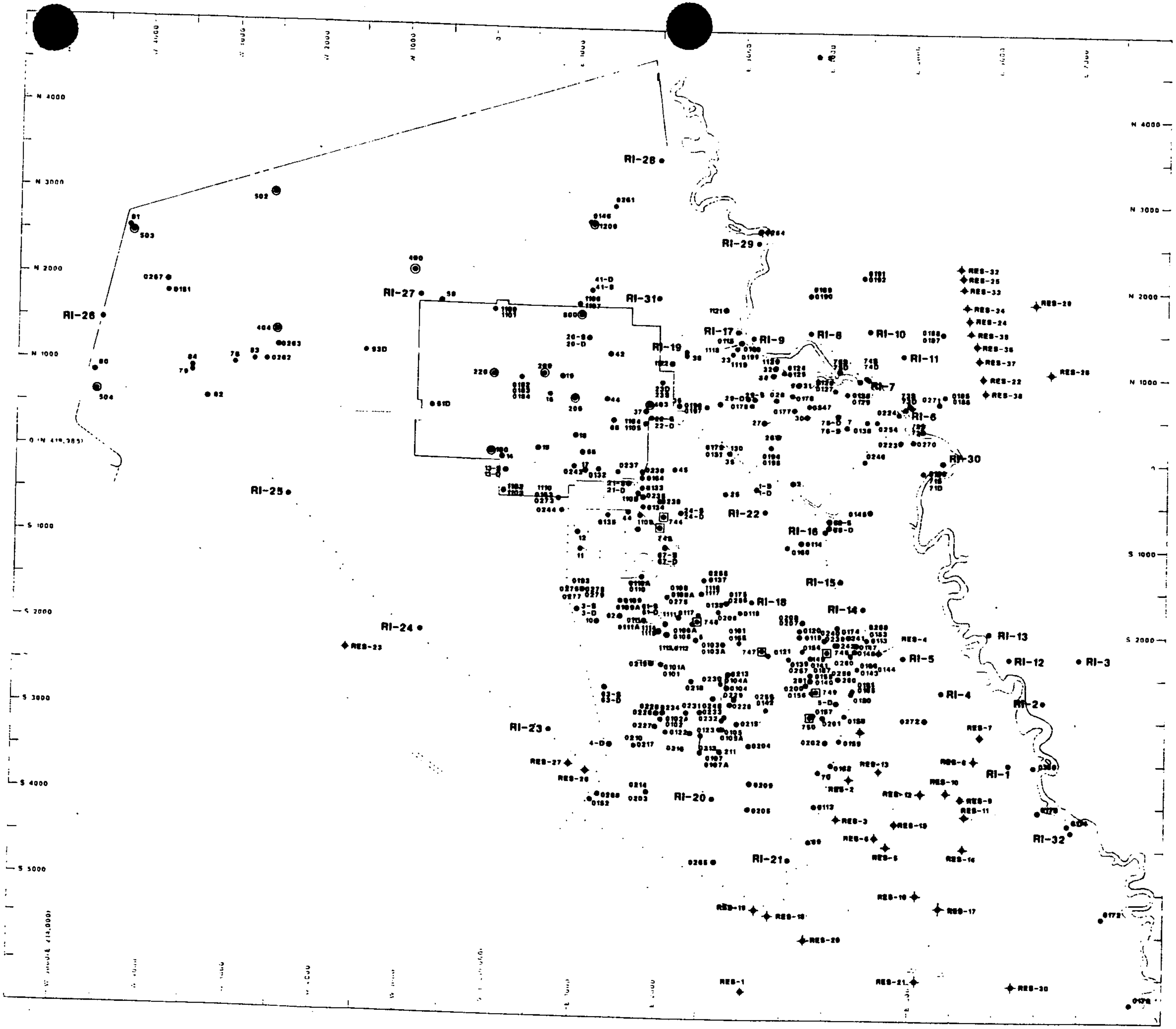
NUS CORPORATION

Figure 4-10 presents a location map of NUS/EPA, AWARE, and residential wells. An inventory of these wells is provided in Appendix D-2.

Geophysical borehole logging was conducted utilizing a natural gamma-ray logging tool. A total of 35 monitoring wells were logged and are listed in Table 4-4. Due to the poor quality of these logs they were not used in this report (Appendix D-7B).

4.2.2 Results of the Lithologic Investigation

Interpretations of subsurface conditions at the Ciba-Geigy Site are based on well logs from both EPA and AWARE wells (Appendices D-1, D-2, D-6, D-8 through D-11). To illustrate the geology, four cross sections have been constructed and presented as Plates 2 through 5. The distribution and depths of on- and off-site wells are adequate to accurately describe the site lithology and to correlate stratigraphy to an elevation of 100 feet below mean sea level (MSL). A small number of deep on-site wells and off-site wells provide limited stratigraphic information for depths greater than 100 feet below MSL. Cross sections A-A', B-B', and C-C' (Plates 2, 3, and 4) were selected to give a comprehensive view of site lithology and were set up in such a way as to maximize the use of EPA well logs; the well logs completed by AWARE did not undergo the same QA/QC procedures and were therefore used only in areas where no EPA well logs exist. Cross section D-D' (Plate 5) was chosen to illustrate the geologic conditions beneath two potential contaminant source areas, the Active Landfill and Filtercake Disposal Area. Figure 4-11 shows the cross section lines and wells used.



WELL LOCATION MAP OF ALL WELLS ON THE CIBA-GEIGY PROPERTY AND SURROUNDING AREA

LEGEND

—+—+—	RAILROAD SPUR
—·—·—	SURVEYED BOUNDARY
—··—··—	BOUNDARY FENCE
- - - - -	BOUNDARY ROAD
● RI-5	EPA MONITORING WELL
● 0120	CIBA-GEIGY MONITORING WELL OR PIEZOMETER
◉	CIBA-GEIGY PRODUCTION WELL
⊞	CIBA-GEIGY PURGING WELL
✦	RESIDENTIAL WELL

* WELL LOCATIONS MAY NOT BE EXACT DUE TO SCALE

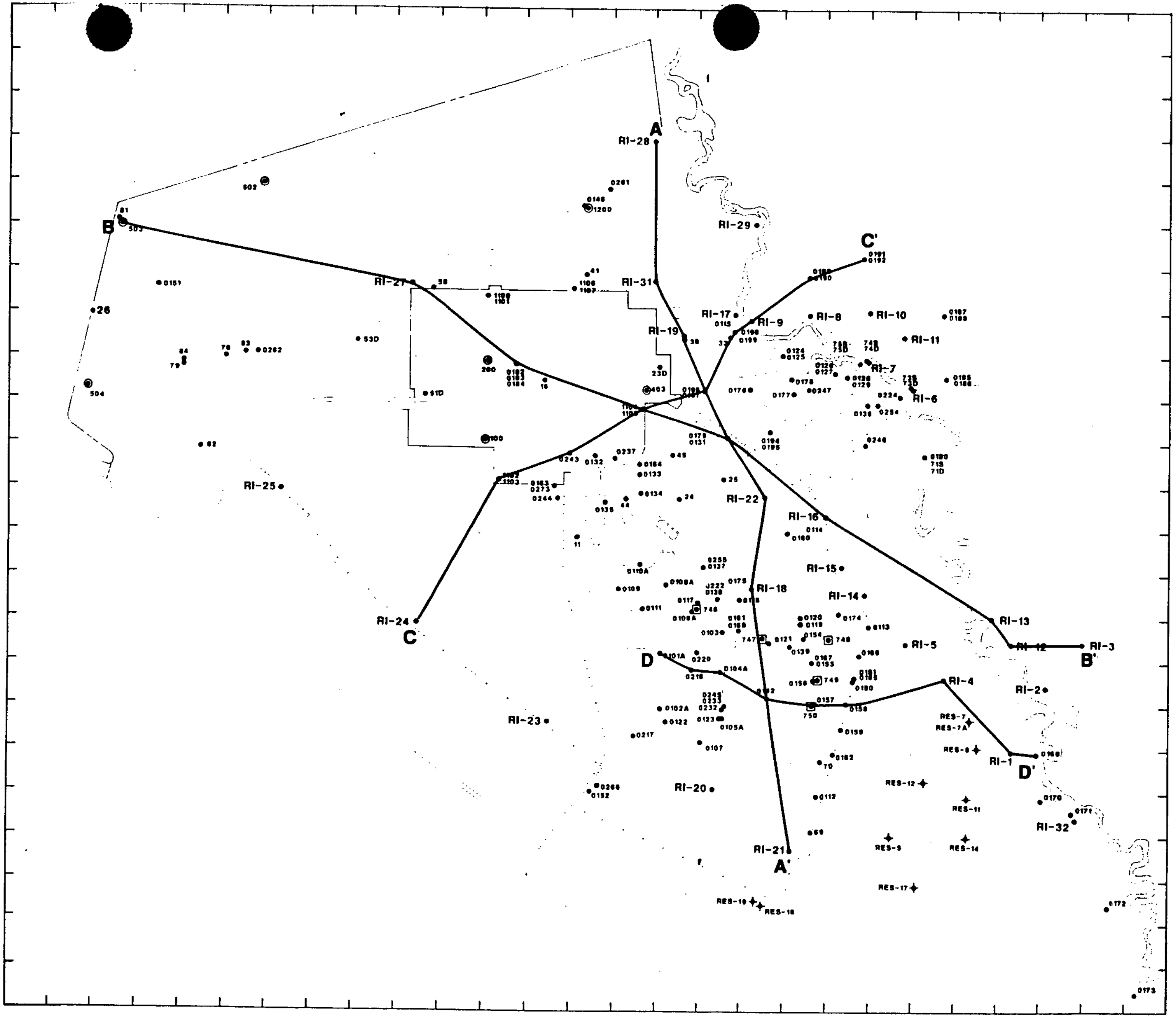
FIGURE 4-10

NUS CORPORATION

TABLE 4-4

WELLS GAMMA-RAY LOGGED BY NUS

RI-1XD
RI-2XD
RI-3XD
RI-4D
RI-5D
RI-6
RI-7
RI-8
RI-9
RI-10XD
RI-11XD
RI-12D
RI-13D
RI-14D
RI-15
RI-16
RI-19D
RI-20D
RI-21XD
RI-22D
RI-23D
RI-24D
RI-25
RI-26
RI-27XD
RI-28D
RI-29D
RI-31D
RI-32XD
RI-32D
0115
0175
0179
0180
0181



LINES OF CROSS SECTION

LEGEND:

- ┼ RAILROAD SPUR
- SURVEYED BOUNDARY
- BOUNDARY FENCE
- BOUNDARY ROAD
- ● RI-5 EPA MONITORING WELL
- ● 0126 CIBA-GEIGY MONITORING WELL OR PIEZOMETER
- ◉ CIBA-GEIGY PRODUCTION WELL
- ▣ CIBA-GEIGY PURGING WELL
- ✦ RESIDENTIAL WELL
- CROSS SECTION

FIGURE 4-11

NUS CORPORATION

The sediments beneath the site are predominantly sands with lesser amounts of clay, silt, and gravel. Three continuous lithologic units are beneath the Ciba-Geigy Site, informally named for this report as the lower sand unit, silt and clay unit, and upper sand unit. The following sections describe these units in more detail based on grain sizes, presence of minor constituents, and stratigraphy. The physical descriptions are based on the Unified Soil Classification and the Burmister Soil Identification Systems.

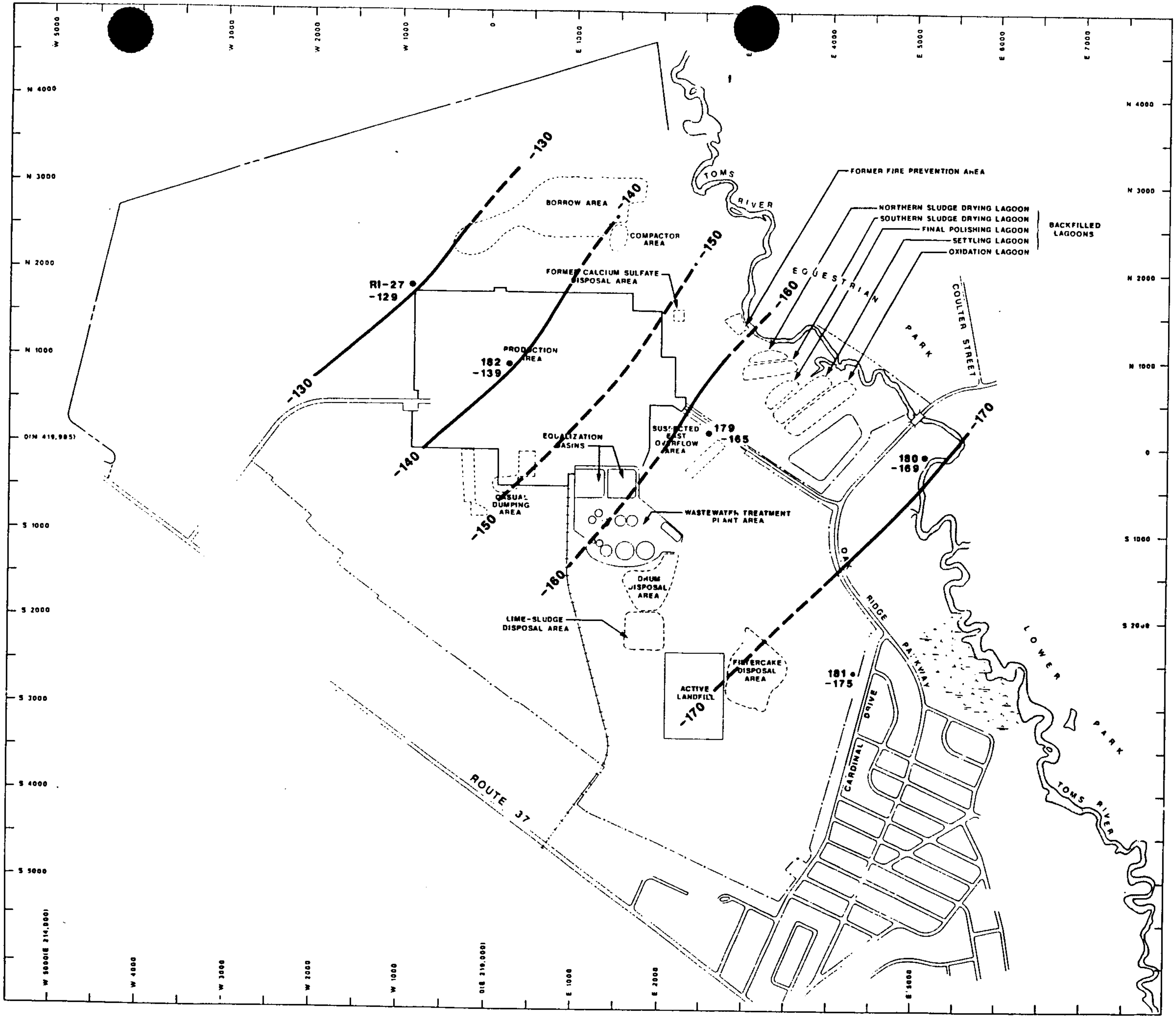
Lower Sand Unit

The five deepest wells at the Ciba-Geigy Site penetrate the lower sand unit, the deepest continuous lithologic unit encountered at the site. These wells (179, 180, 181, 182, and RI-27XD) are plotted on a structural contour map showing the upper surface of the lower sand unit (Figure 4-12). The elevation of sand ranges from 129 to greater than 175 feet below MSL; the base of the unit was not reliably documented in on-site wells. Although data are limited, the unit appears to be a monocline dipping east-southeast.

The lower sand unit consists primarily of fine- to medium-grained sands, but some very fine- and coarse-grained sands are present. Clay and silt size particles are abundant and the sand is often silty or clayey. Mica and glauconite appear in nearly all samples from this unit. Where glauconite is present, a greenish shade is added to the usual brown and gray color of the sand.

Silt and Clay Unit

Overlying the lower sand unit is the silt and clay unit (Plates 2 and 3). Limited data indicates a gradational contact with the underlying lower sand unit. The upper contact of the silt and clay unit, characterized from nine well logs, shows an abrupt change in lithology from clay and silt to that of the overlying sands. The



STRUCTURE CONTOUR MAP OF THE UPPER SURFACE OF LOWER SAND UNIT

LEGEND

┼┼┼ RAILROAD SPUR

—·—·— SURVEYED BOUNDARY

—·—·— BOUNDARY FENCE

- - - - BOUNDARY ROAD

-160 —— CONTOUR LINE, APPROXIMATED

● 179 ← MONITORING WELL

-165 ← ELEVATION AT WELL

-160 — — INFERRED CONTOUR LINE

FIGURE 4-12

NUS CORPORATION

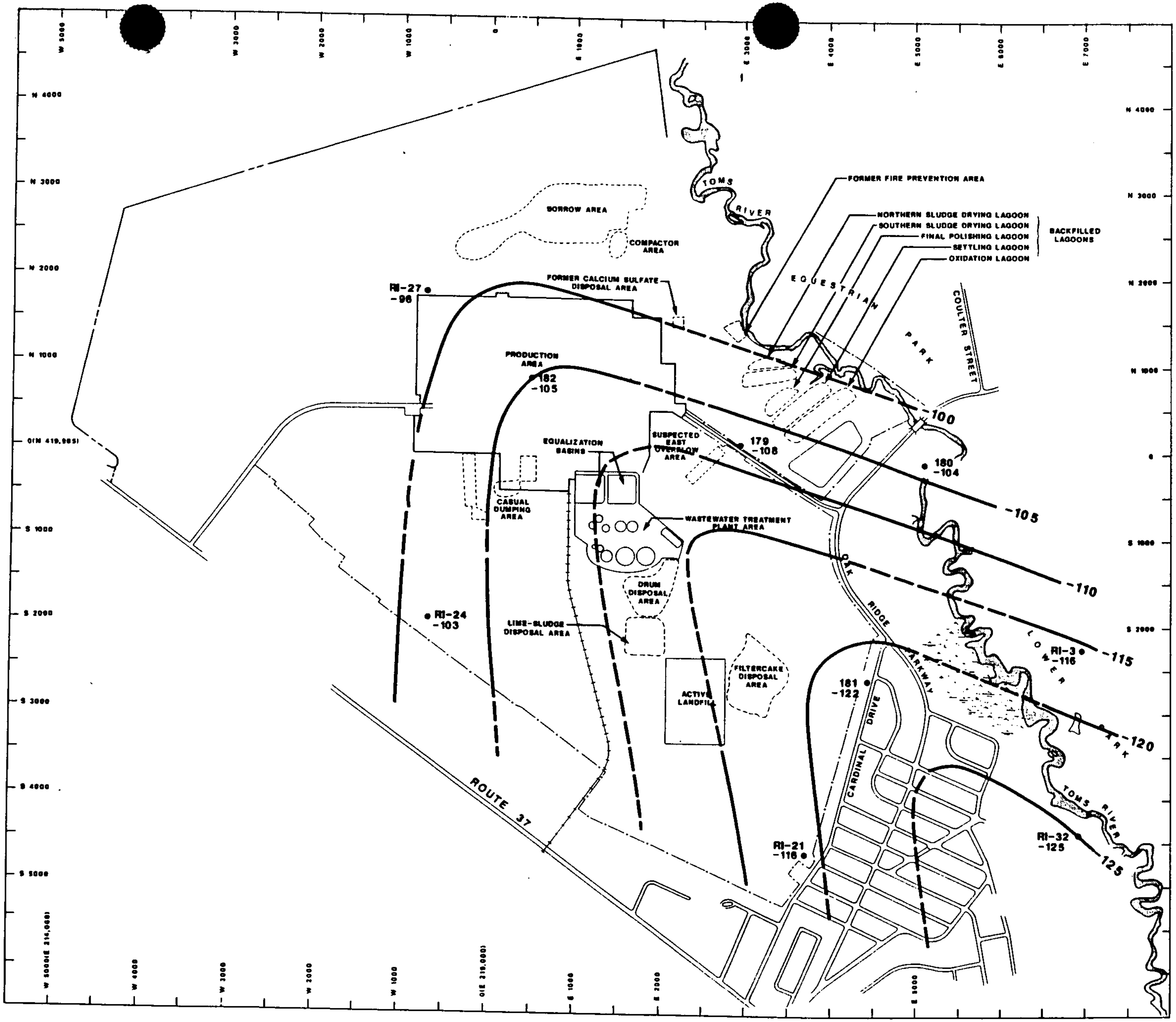
upper surface of the silt and clay unit is apparently a synform plunging toward the southeast (Figure 4-13). The elevation of the upper surface ranges from 96 feet below MSL (RI-27XD) to 125 feet below MSL (RI-32XD). The observed thickness of the silt and clay unit ranges from 33 to 65 feet, with the unit thickening to the southeast (Figure 4-14).

The lithology of the silt and clay unit is not homogeneous; it consists of interbedded silt and clay units, commonly containing sand lenses. Wells 179 and RI-3XD are screened in sand interbeds, and a sand lens is noted between wells RI-27XD and 182 (Plate 3). Also common are interbeds of sandy clay and silty sand. The color of the silt and clay unit differs little from the underlying sand. It is brown, gray, and where glauconite is present, green.

Upper Sand Unit

The upper sand unit is the most studied lithologic unit at the site, but also the most complex. It consists of all sediment above the silt and clay unit and occupies the uppermost 120 to 210 feet of the stratigraphic column, occurring between ground surface and, at its lowest elevation, 125 feet below MSL. Although the unit is predominantly sand, its profile is often marked by discontinuous beds of silt and clay.

The upper sand unit is generally a coarsening upward sequence. The sediment immediately above the silt and clay unit is composed largely of very fine- to fine-grained sand. Moving upward from the silt and clay unit, the sand constituent becomes of larger grain size; more medium-grained sands and less very fine-grained sands are evident. Across a 10 to 15 foot vertical zone varying between elevations of 10 and 44 feet below MSL, the grain size changes from fine to predominantly coarse with some very coarse-grained sands. Other notable changes in lithology occurring during this interval is the appearance of gravel and the disappearance of mica. Also between elevations of 10 and 44 feet below MSL, the duller gray and brown color of the lower portion of the upper sand unit gives way to lighter colors, particularly yellow and orange.



STRUCTURE CONTOUR MAP OF THE UPPER SURFACE OF SILT AND CLAY UNIT

LEGEND

—+—+— RAILROAD SPUR

—·—·— SURVEYED BOUNDARY

—··—··— BOUNDARY FENCE

- - - - - BOUNDARY ROAD

-115 — — — INFERRED CONTOUR LINE

-110 ——— CONTOUR LINE, APPROXIMATED.

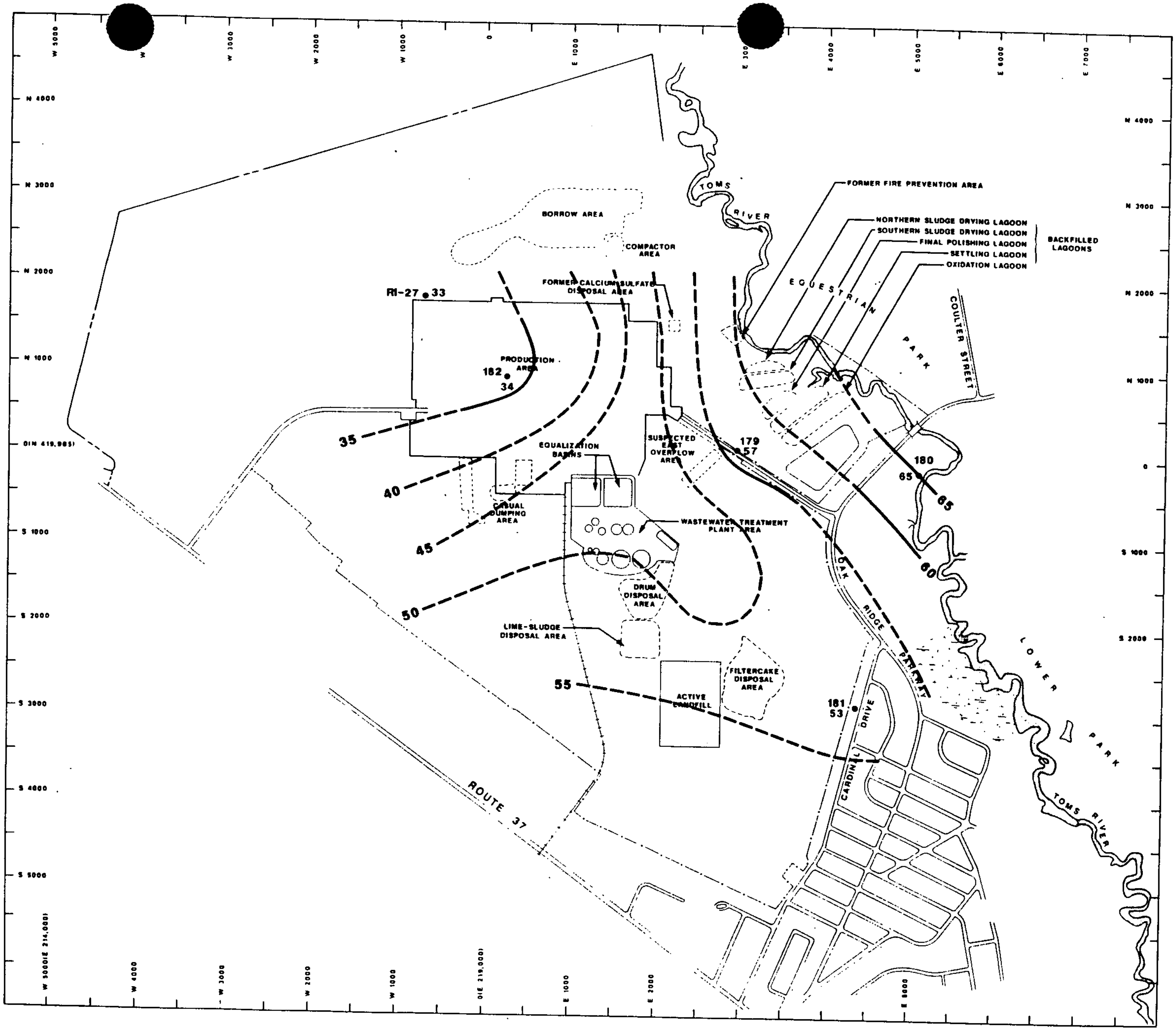
● 180 ← MONITORING WELL

-104 ← ELEVATION AT WELL

FIGURE 4-13

NUS CORPORATION

ISOPACH MAP OF SILT AND CLAY UNIT



LEGEND

-+-+- RAILROAD SPUR
— - — SURVEYED BOUNDARY
— · · — BOUNDARY FENCE
- - - - - BOUNDARY ROAD
50 ——— ISOPACH LINE
50 — — — INFERRED ISOPACH LINE
● 161 MONITORING WELL
53 UNIT THICKNESS AT WELL (FT.)

FIGURE 4-14

NUS CORPORATION

The coarsening upward sequence noted above is disrupted by a large, dark-colored lens of fine-grained sand and silt. The center of the lens is located southeast of the Production Area; its long axis roughly follows cross section line B-B' (Plate 3). The lens can also be seen clearly on cross sections A-A' and C-C' (Plates 2 and 4). Section D-D' (Plate 5) appears to be beyond the southern limit of the lens, but this may reflect a lack of information in the area due to the shallowness of wells. The established southern limit is at well 747 (Plate 2), while the northern limit is well 196 (Plate 2). The furthest extent east and west is seen in wells RI-16 and 182, respectively (Plate 3). Cross section C-C' (Plate 4) shows the lens between wells 1104/RI-22D and 33, but when compared with the shape and size of the lens shown in Sections A-A' and B-B', it seems proportionally small. This size difference may result from a lack of deep lithologic data to the southwest of well 1104/RI-22D. The composition of the lens varies between wells, however, the dominant lithology is very fine- to fine-grained sand that is silty or clayey. Some clay and silt beds are present in the lens grading laterally to coarser or finer material.

At various locations and elevations in the upper sand unit, pockets of dark sand were encountered ranging in color from brownish black to grayish black with an occasional reddish black bed. Grain sizes of these "black" sands vary greatly, ranging from very-fine to very-coarse with occasional silt and clay interbeds. These units are located primarily at the east end of the site where they occur in small lenses averaging approximately 4 feet in thickness.

A complex series of clay beds underlie a large portion of the site from the Production Area to Cardinal Drive and east of the Production Area to wells on the east side of the Toms River (Plate 10). These beds range in thickness from 0 to 19 feet and are found at elevations ranging between 62 feet above MSL and 38 feet below MSL. By mapping clay occurrences (Plates 6 through 12) and examining their gross physical changes it is apparent that these clay beds are not connected, but rather discontinuous units that "pinch out" or grade laterally into sands or silts.

At several localities, namely the southern portion of the Production Area, the northern half of the Wastewater Treatment Plant, and the Backfilled Lagoons Area, wells may be too shallow to have encountered any clay. Additional deep wells may be required in these areas to fully define the extent of the clay beds. Fewer and less extensive clay beds mapped at the perimeter of the site may be due in part to less lithologic information in these areas.

The clay beds contain trace to moderate amounts of silt, sand, and gravel with dominant colors of yellow, gray, and brown. At several locations clayey silt or clayey sands were found at the same elevation as a nearby clay bed, indicating lateral grading.

4.3 Description of Site Aquifer Hydraulic Characteristics

Hydraulic conductivity testing of the units beneath the Ciba-Geigy Site has been performed both by NUS and by contractors for AWARE Corporation. The data obtained from these tests provide an understanding of aquifer hydraulics and site geohydrology. Sections 4.3.1, 4.3.2, 4.3.3, 4.3.4, and 4.3.5 discuss the objectives, background information, test equipment and methodology, results of hydraulic conductivity testing, and conclusions respectively.

4.3.1 Objective

The objective of the testing was to obtain representative hydraulic conductivity values for each lithologic unit identified during the subsurface investigation. The hydraulic conductivity values, the areal distribution and thickness of each lithologic unit, along with the water level measurements from piezometers and monitoring wells will be used to evaluate the horizontal and vertical components of groundwater flow in Section 4.4.

The hydraulic conductivity data will also be used for computer modelling of the horizontal and vertical groundwater flow patterns, and simulation of proposed groundwater remedial alternatives discussed in the Feasibility Study.

4.3.2 Background Information

Hydraulic studies of units beneath the site have used a number of different methods: the bail or slug test (used by NUS), Neuman and Witherspoon Ratio method, Triaxial Cell-Based Test method, constant volume test, constant-discharge aquifer test, a tritium test, Masch and Denny's method based on grain size curves, and Hazen's method based on grain size curves. These methods vary greatly in their ability to accurately characterize the water-transmitting properties of geologic units. For this report, emphasis is placed on field techniques where possible.

4.3.3 Test Equipment and Methodology of the NUS Program

The following sections discuss the equipment and methodology used by NUS in performing the in-situ horizontal hydraulic conductivity tests (slug tests) at the Ciba-Geigy Site.

4.3.3.1 Test Equipment and Procedures

To perform the slug test, a Steco Mini-Pressure Transducer, an Environmental Data Logger, and a stainless steel bailer were used. The Steco Mini-Pressure Transducer was used in conjunction with the Environmental Data Logger, Model DL-240, to record change in head elevations. The stainless steel bailer, with approximately 1,250 cc displacement, was used to remove a volume of water from the well. For the operation of the data logger, 20 millivolts was selected; for the recording chart speed, 60 or 300 millimeters per minute was selected.

Wells were selected to test the aquifer's hydraulic conditions within site-important stratigraphic units located on either side of the Toms River. The slug test was conducted on 30 wells. The test procedure was as follows:

- The water level of the well was measured.

- The transducer was placed below the level of the water.
- The bailer was placed below the level of the water.
- The data logger was allowed to equilibrate with the water level.
- The bailer was quickly pulled from the well to create a sudden water level decline.
- Data were collected in terms of recharge versus time.

The data logger recorded the well recovery on the paper chart until the water level recovered 90 percent of its loss. The bail test was duplicated for 26 of the 30 tested wells; the remaining 4 wells recharged too slowly for retesting.

4.3.3.2 Calculation of Hydraulic Conductivity

The hydraulic conductivity of the saturated soil in the proximity of the screen can be determined using the following equation by Cedergren (1977), modified from Hvorslev (1951):

$$K = \frac{r^2}{2\,L\,(t_2-t_1)} \quad \ln(L/R) \times \ln(h1/h2)$$

Where: K = hydraulic conductivity (centimeters/second)
h_1 = head ratio at time t_1 (dimensionless)
h_2 = head ratio at time t_2 (dimensionless)
t_1 = time corresponding to h_1 (seconds)
t_2 = time corresponding to h_2 (seconds)
L = length of screen (centimeters)
r = screen radius (centimeters)
R = gravel pack radius (centimeters)

4.3.3.3 Limitations of the Test Method

The following are some of the limitations inherent to in-situ slug tests:

- The slug test can only approximate the hydraulic conductivity in the interval of the well screen.

- The disturbance to the formation caused by drilling, well development, and the potential for turbulent flow through the well screen may cause underestimation of actual hydraulic conductivity.
- Effective well diameter varies with installation and well development technique.
- The Cedergren (1977) equation assumes an isotropic unconfined aquifer of infinite thickness or confined aquifer of thickness between 1.2L and 5L, where L is the screen length of the tested well.

4.3.4 Results of Site Aquifer Hydraulic Conductivity Testing

The results of the horizontal hydraulic conductivity testing performed by both NUS and AWARE are presented in this section and discussed as they pertain to the geology of the site.

4.3.4.1 Results of NUS Hydraulic Conductivity Program

The results of slug tests conducted by NUS are presented in Table 4-5 and Figure 4-15. A complete description of screen elevations, lithology surrounding the well, and hydraulic conductivity can be found in Appendix D-7A.

Lower Sand Unit

Only one slug test was conducted by NUS on a well screened in the lower sand unit. The horizontal hydraulic conductivity determined from this test, 5.8×10^{-4} cm/sec, is from an interval with unusually high silt and clay content. No determination of hydraulic conductivity for the lower sand unit can be made on the basis of this single measurement.

Silt and Clay Unit

The average horizontal hydraulic conductivity of the silt and clay unit was 2.0×10^{-2} cm/sec as determined from slug tests of two wells screened near the lower contact of the unit. The sediments at the screened interval of these wells are medium- to

TABLE 4-5
HYDRAULIC CONDUCTIVITY RESULTS

Well No.	L (cm)	R (cm)	r (cm)	t_2-t_1 (sec)	h^1/h^2	K (cm/sec)
RI-3S	185.9	11.11	5.08	30-5	0.70/0.20	$9.8\text{x}10^{-3}$
RI-3D	335.3	11.11	5.08	30-5	0.65/0.16	$7.4\text{x}10^{-3}$
RI-3XD	182.9	11.11	5.08	10-2	0.76/0.24	$2.8\text{x}10^{-2}$
RI-5S	335.3	11.11	5.08	100-5	0.79/0.33	$1.2\text{x}10^{-3}$
RI-5D	335.3	10.16	5.08	100-5	0.93/0.33	$1.5\text{x}10^{-3}$
RI-7	207.3	11.11	5.08	30-5	0.70/0.22	$8.4\text{x}10^{-3}$
RI-9	182.9	11.11	5.08	40-5	0.74/0.23	$6.6\text{x}10^{-3}$
RI-15S	338.3	11.11	5.08	60-5	0.61/0.11	$4.1\text{x}10^{-3}$
RI-15D	335.3	11.11	5.08	30-5	0.71/0.16	$7.8\text{x}10^{-3}$
RI-17	182.9	10.16	5.08	50-5	0.77/0.25	$5.1\text{x}10^{-3}$
RI-21S	182.9	11.11	5.08	50-5	0.86/0.20	$6.4\text{x}10^{-3}$
RI-21D	335.3	11.11	5.08	10-1	0.89/0.24	$1.9\text{x}10^{2}$
I-21XD	182.9	11.11	5.08	30-5	0.66/0.15	$1.2\text{x}10^{-2}$
RI-22S	182.9	10.00	5.08	100-5	0.93/0.46	$1.5\text{x}10^{-3}$
RI-22D	335.3	11.11	5.08	50-5	0.85/0.24	$3.7\text{x}10^{-3}$
RI-27S	182.9	11.11	5.08	60-5	0.88/0.26	$4.4\text{x}10^{-3}$
RI-27D	335.3	11.11	5.08	30-5	0.71/0.19	$6.9\text{x}10^{-3}$
RI-27XD	182.9	11.11	5.08	300-5	0.97/0.41	$5.8\text{x}10^{-4}$
RI-28S	335.3	11.11	5.08	5-1	0.77/0.22	$4.1\text{x}10^{-2}$
RI-28D	335.3	11.11	5.08	20-5	0.60/0.17	$1.1\text{x}10^{-2}$
RI-29S	182.9	11.11	5.08	5-1	0.76/0.30	$4.6\text{x}10^{-2}$
RI-29D	335.3	11.11	5.08	40-5	0.77/0.23	$4.5\text{x}10^{-3}$
RI-31	152.4	10.00	5.08	80-5	0.92/0.35	$3.0\text{x}10^{3}$
I-31D	335.3	10.00	5.08	20-5	0.57/0.13	$1.3\text{x}10^{-2}$
0155	304.8	5.08	5.08	30-5	0.70/0.13	$1.2\text{x}10^{-2}$
0167	304.8	5.08	5.08	50-5	0.86/0.46	$2.4\text{x}10^{-3}$
0196	304.8	10.16	5.08	40-5	0.77/0.23	$5.0\text{x}10^{-3}$
0197	304.8	10.16	5.08	100-5	0.91/0.42	$1.2\text{x}10^{-3}$
0198	304.8	10.16	5.08	20-5	0.75/0.23	$1{:}1\text{x}10^{-2}$
0199	304.8	10.16	5.08	30-5	0.81/0.39	4.2x10-3

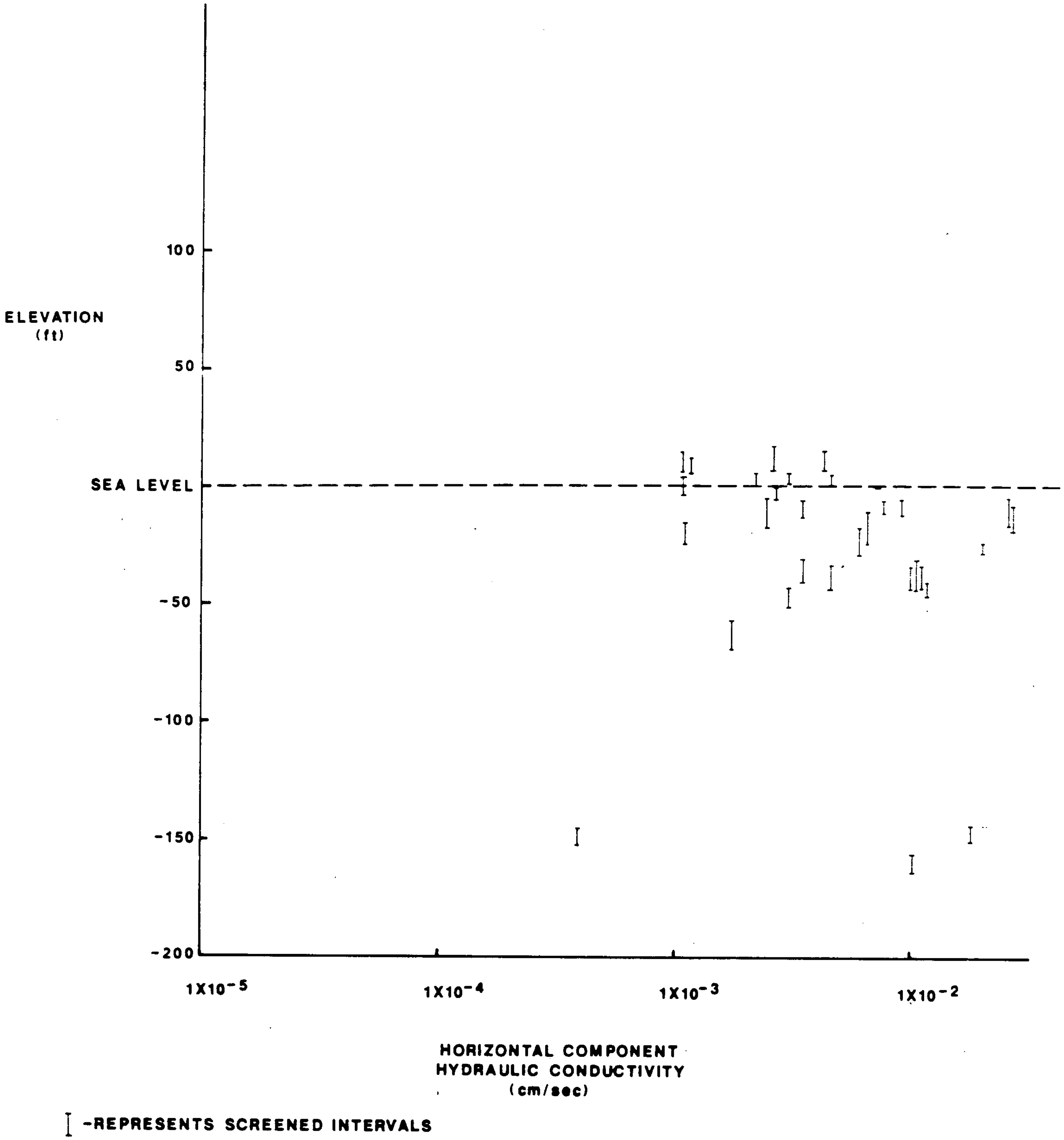


FIGURE 4-15

ELEVATION VERSUS HYDRAULIC CONDUCTIVITY

CIBA-GEIGY, DOVER TWP., N.J.

(TESTS PERFORMED BY NUS)

NUS CORPORATION

coarse-grained sands with varying amounts of clay and silt, part of the transitional boundary between the silt and clay unit and the lower sand unit. The hydraulic conductivity value, therefore, may be misleading because the lithology at the screened interval is not representative of the dominant lithology of the unit.

Upper Sand Unit

The horizontal hydraulic conductivity of the upper sand unit is calculated from slug tests of 27 wells with screen elevations ranging from +20 to -50 feet MSL (Figure 4-16). The arithmetic mean of these values is 9.2×10^{-3} cm/sec. No consistent change in hydraulic conductivity with elevation is noted.

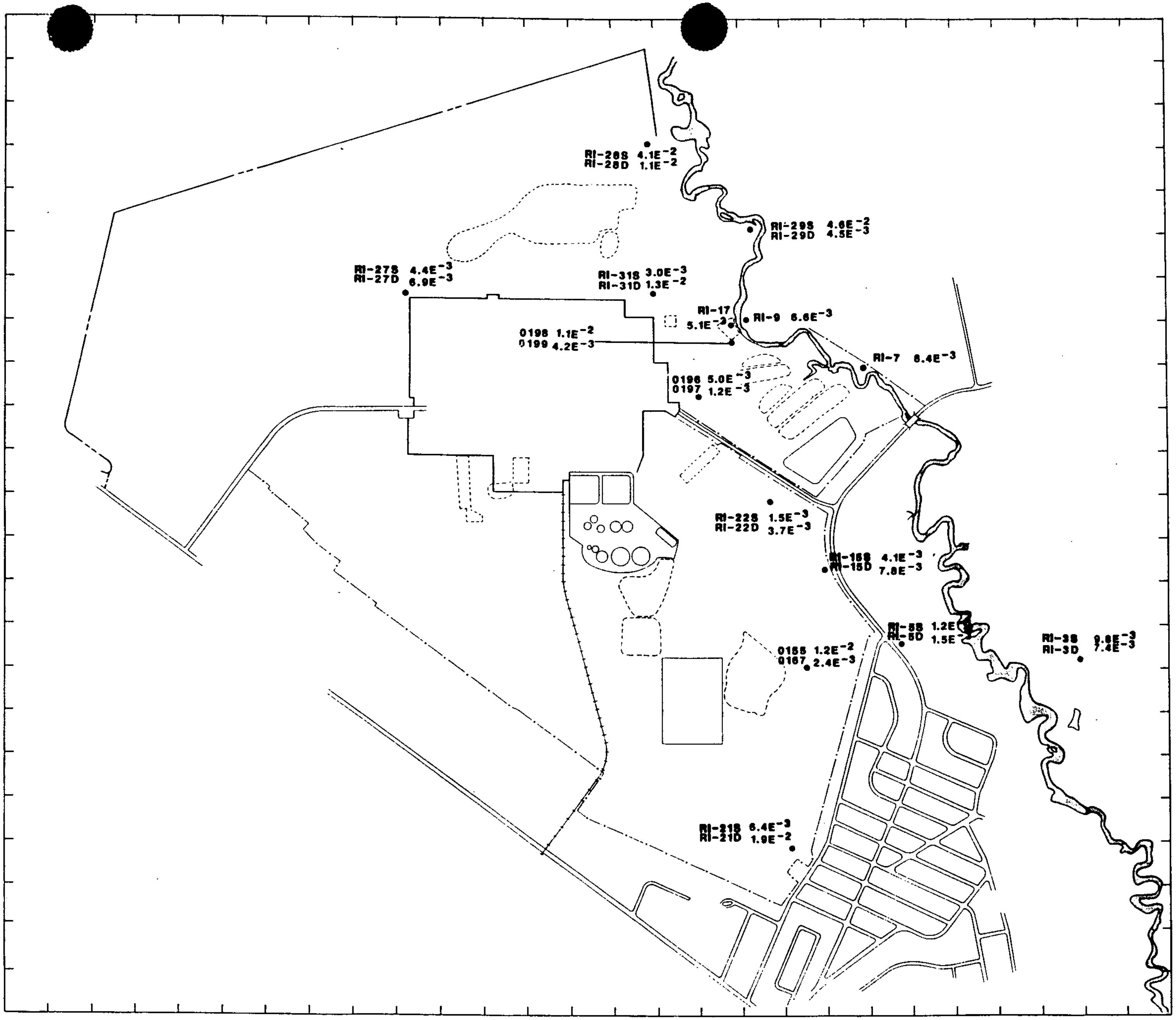
4.3.4.2 Results of AWARE's Hydraulic Conductivity Program

AWARE Corporation has conducted a detailed program of measuring and calculating hydraulic conductivity values for geologic units at the Ciba-Geigy Site (Appendix D-7B). The methodology of the testing done by AWARE and others may be found in the AWARE, Hydrologic and Related Environmental Investigation, Volume 1, 1986, for the Ciba-Geigy Corporation, Toms River Plant, and the Geonics, Phase 3 Geo-Hydrological Investigation of the Cardinal Drive Area, 1983, for the Ciba-Geigy Corporation, Toms River Plant. In-situ slug test results are summarized in Figure 4-17.

Slug tests tend to be less reliable than aquifer pump tests, usually underestimating the hydraulic conductivity of a unit. Therefore, AWARE applies an "adjustment factor" of between 2 and 3 to hydraulic conductivities determined from slug tests.

Lower Sand Unit

AWARE has performed three in-situ slug tests of the "Kirkwood No. 2 Sand", which corresponds to the lower sand unit discussed in this report. The arithmetic mean of these three values is 6.7×10^{-3} cm/sec.



HYDRAULIC CONDUCTIVITIES OF WELLS SCREENED IN THE UPPER SAND UNIT TESTED BY NUS

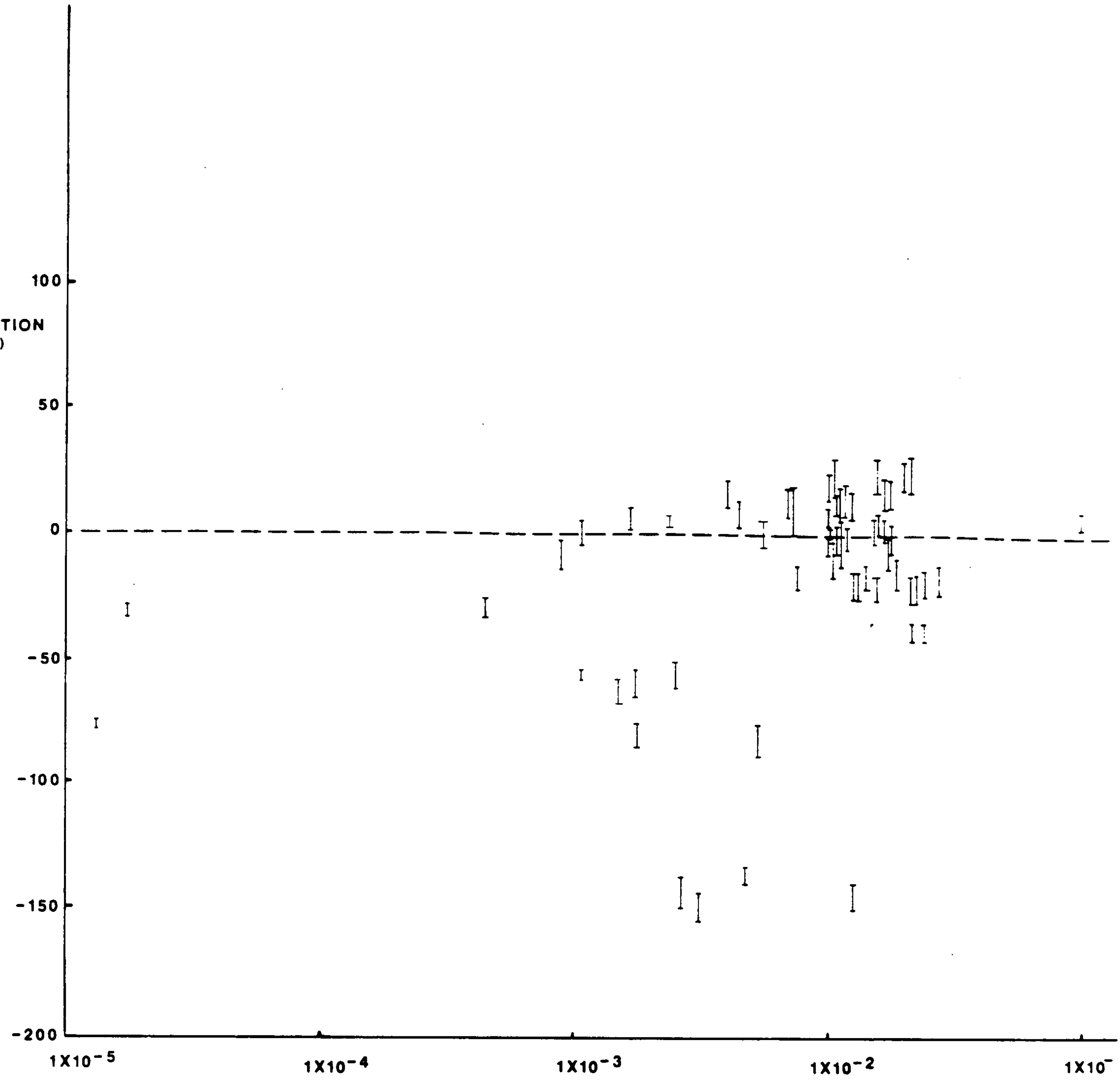
LEGEND

┼┼┼	RAILROAD SPUR
—·–·—	SURVEYED BOUNDARY
—··—··	BOUNDARY FENCE
-------	BOUNDARY ROAD
●	WELL LOCATIONS

(NUMBERS ALONG SIDE OF WELL ARE HORIZONTAL HYDRAULIC CONDUCTIVITY VALUES, REPRESENTED IN cm/sec)

FIGURE 4-16

NUS CORPORATION



NOTE:
ANOTHER 5 WELLS ARE LOCATED BETWEEN 1.5×10^{-2} AND 1.7×10^{-2}

I -REPRESENTS SCREENED INTERVALS

FIGURE 4-17

ELEVATION VERSUS HYDRAULIC CONDUCTIVITY

CIBA-GEIGY, DOVER TWP., N.J.

(TESTS PERFORMED BY AWARE)

NUS CORPORATION

Silt and Clay Unit

AWARE (1986) reports vertical hydraulic conductivities determined from Shelby tube samples taken from the "Primary Kirkwood". From these three laboratory tests, the "Primary Kirkwood", which corresponds to the silt and clay unit has an estimated hydraulic conductivity of 1.0 x 10^{-5} cm/sec.

Upper Sand Unit

AWARE (1986) divides the upper sand unit into five subunits based on lithology. From deepest to shallowest, these units are named "Kirkwood No. 1 Sand," "Upper Kirkwood," "Lower Cohansey," "Cohansey/Kirkwood Transitional Unit", and "Primary Cohansey". Table 4-6 provides a summary of methods and hydraulic conductivities determined for each of these subunits. Although each unit appears hydraulically distinct based on the estimated hydraulic conductivites reported by AWARE for the "Upper Kirkwood" and "Cohansey/Kirkwood Transitional Unit", three points should be noted:

- The "Upper Kirkwood" is assigned a vertical hydraulic conductivity of 1.0x10^{-4} cm/sec. This value was determined by a combination of the Neuman and Witherspoon ratio method and tritium testing. Problems exist with the interpretation of this tritium data and therefore hydraulic conductivities calculated from tritium data were not used in this report.

- The Neuman and Witherspoon ratio method indicates a vertical hydraulic conductivity of 1.2 x 10^{-3} cm/sec for the upper 35 feet of the "Upper Kirkwood". Horizontal hydraulic conductivity for this section of the aquifer is likely to be significantly higher.

- Hydraulic conductivity of the "Kirkwood/Cohansey Transitional Unit" is based on a single laboratory measurement. AWARE indicates that laboratory tests tend to underestimate hydraulic conductivity because they "often fail to predict the influence of macro-scale features on aquitard behavior" (AWARE 1986, p. 4-41). Given also that this measurement is of vertical hydraulic conductivity, it is not unreasonable that the effective horizontal conductivity of this unit could be 1x10^{-3} cm/sec or more.

TABLE 4-6
SUMMARY OF HYDRAULIC CONDUCTIVITY TESTING PERFORMED BY NUS AND AWARE

NUS Hydraulic Conductivity Estimates				AWARE Hydraulic Conductivity Estimates		
Lithologic Unit	Hydrogeologic Unit	Hyd. Conductivity (cm/sec)	Method	Lithologic/ Hydrogeologic Unit	Hyd. Conductivity (cm/sec)	Method
				Primary Cohansey	4.5x10^{-2} (Horizontal)	Estimate from various aquifer tests
				Cohansey/ Kirkwood Transitional Unit	1.0x10^{-4} (Vertical)	Shelby tube test
upper sand unit	unconfined upper sand aquifer	9.2x10^{-3} (Horizontal)	Average of 27 NUS slug tests	Lower Cohansey	3.9x10^{-2} (Horizontal)	1956 aquifer test
				Upper Kirkwood	1.0x10^{-4} (Vertical)	Neuman-Witherspoon ratio method, tritium analysis
				Kirkwood No. 1 Sand	1.5x10^{-2} (Horizontal)	Average of 2 slug tests with "adjustment factor" of 3.0
silt and clay unit	silt and clay semiconfining layer	1.0x10^{-5} (Vertical)	Average of 3 Shelby tube tests reported by AWARE	Primary Kirkwood	1.0x10^{-5} (Vertical)	Average of 3 Shelby tube tests reported by AWARE
lower sand unit	semiconfined lower sand aquifer	5.2x10-3 (Horizontal)	Average of 1 NUS and 3 AWARE slug tests	Kirkwood No. 2 Sand	2.1x10-2 (Horizontal)	Average of 3 slug tests with "adjustment factor" of 3.0

4.3.5 Conclusions of Hydraulic Conductivity Testing

The results of hydraulic conductivity testing performed by NUS and AWARE indicate the following:

- The lower sand unit has a horizontal hydraulic conductivity of approximatley 5.2×10^{-3} cm/sec determined from the arithmetic mean of one NUS and three AWARE in-situ slug tests.
- The silt and clay unit has a vertical hydraulic conductivity of approximately 1.0×10^{-5} cm/sec based on the average of 3 triaxial Shelby tube tests reported by AWARE (1986).
- The upper sand unit has an average horizontal hydraulic conductivity of 9.2×10^{-3} cm/sec based on the arithmetic mean of 27 in-situ slug tests performed by NUS. This should be considered a minimum value as the method used tends to underestimate actual hydraulic conductivity.
- No consistent change in hydraulic conductivity with depth is noted from slug tests.

4.4 Site Hydrogeology Overview

This section combines the major elements from the sections 4.1, 4.2, and 4.3 in order to describe the aquifer system and to determine contaminant migration potential within the system. The major elements discussed are piezometric surfaces and contaminant migration potential.

4.4.1 Piezometric Surfaces

Piezometric surfaces were used to determine groundwater flow direction for continuous water-bearing units at the site. This section presents the methods used, and the piezometric surfaces determined for the lower sand unit and upper sand unit.

4.4.1.1 Methods

Piezometric surfaces are used to indicate horizontal groundwater flow direction through a given aquifer by contouring water level measurements from piezometers or wells. They are limited in their ability to characterize general groundwater flow by factors relating to the monitoring devices from which measurements are taken. Factors that can cause inconsistency in water level measurements between wells include:

- Unrepresentative lithology at the screened interval
- Perched water tables
- Variations in well construction and development techniques
- Vertical components of groundwater flow

To minimize the influence of these factors, piezometric surfaces presented here are calculated with measurements from wells drilled by NUS/EPA during the remedial investigation. These wells cover a broad area and are consistent in their construction and lithologic control. Where strong vertical components of groundwater flow are present, wells screened at similar elevations are used for determining piezometric surfaces.

Although the piezometric surface changes through time, it is impractical to present contoured water level data for every date that measurements were taken. Therefore, January 14, 1986 was selected as representative of average groundwater conditions at the site. This decision is based on well hydrographs presented in Appendix D-4. Complete water level measurements are presented in Appendix D-3.

4.4.1.2 Definition of the Hydrogeologic System

Water level measurements from wells screened in the lower sand unit or lower part of the silt and clay unit vary up to 6 feet from wells screened in the upper sand unit. Hydraulic conductivity studies indicate that the silt and clay unit may act as a semiconfining unit for the lower sand unit.

Based on lithologic and hydraulic conductivity studies, the saturated portion of the upper sand unit appears to act as an unconfined aquifer across most of the site, with the possibility of local confinement where discontinuous clay beds are present. A comparison of water levels from shallow (S) and deep (D) NUS wells screened in the upper sand unit show nearly identical measurements except in the case of wells near the Toms River (Table 4-7). Differences in water level measurements from these wells are likely the result of a strong vertical component of groundwater flow near the river.

Separate piezometric surface maps were constructed for the lower sand aquifer and the upper sand aquifer. These aquifers, while recognized as separate beneath the site, are part of the regional Kirkwood-Cohansey aquifer system (Zapecza, 1984). Although locally discussed in terms of "Kirkwood" and "Water-table" aquifers, the Kirkwood Formation and Cohansey Sand are defined on the basis of grain size and sedimentary structures (Carter, 1978). As most sedimentary structures are difficult to identify from split-spoon samples, the boundary between the Kirkwood Formation and the Cohansey Sand can not be accurately identified. Therefore the terms "Kirkwood" or "Cohansey" are not used in this report to describe lithologic or hydrogeologic units. A summary of geologic and hydrogeologic units and their nomenclature is presented in Figure 4-18.

4.4.1.3 Lower Sand Aquifer

The piezometric surface for the lower sand aquifer was constructed using only nine wells, four of which are screened in the transitional zone between the lower sand unit and the silt and clay unit (Figure 4-19). Because of the sparse data for this unit, the map should only be interpreted as representing the most generalized flow. Direction of groundwater flow in this unit is southeastward and eastward at the site with an average gradient of 0.001. Given an average porosity of 0.4, the interstitial groundwater velocity would be approximately 15 feet/year. The piezometric surface does not appear to be affected by influences of the Toms River. This is evident by the absence of a significant change in groundwater flow direction near the river. However, this is not conclusive due to a lack of wells screened in lower sand aquifer east of Toms River.

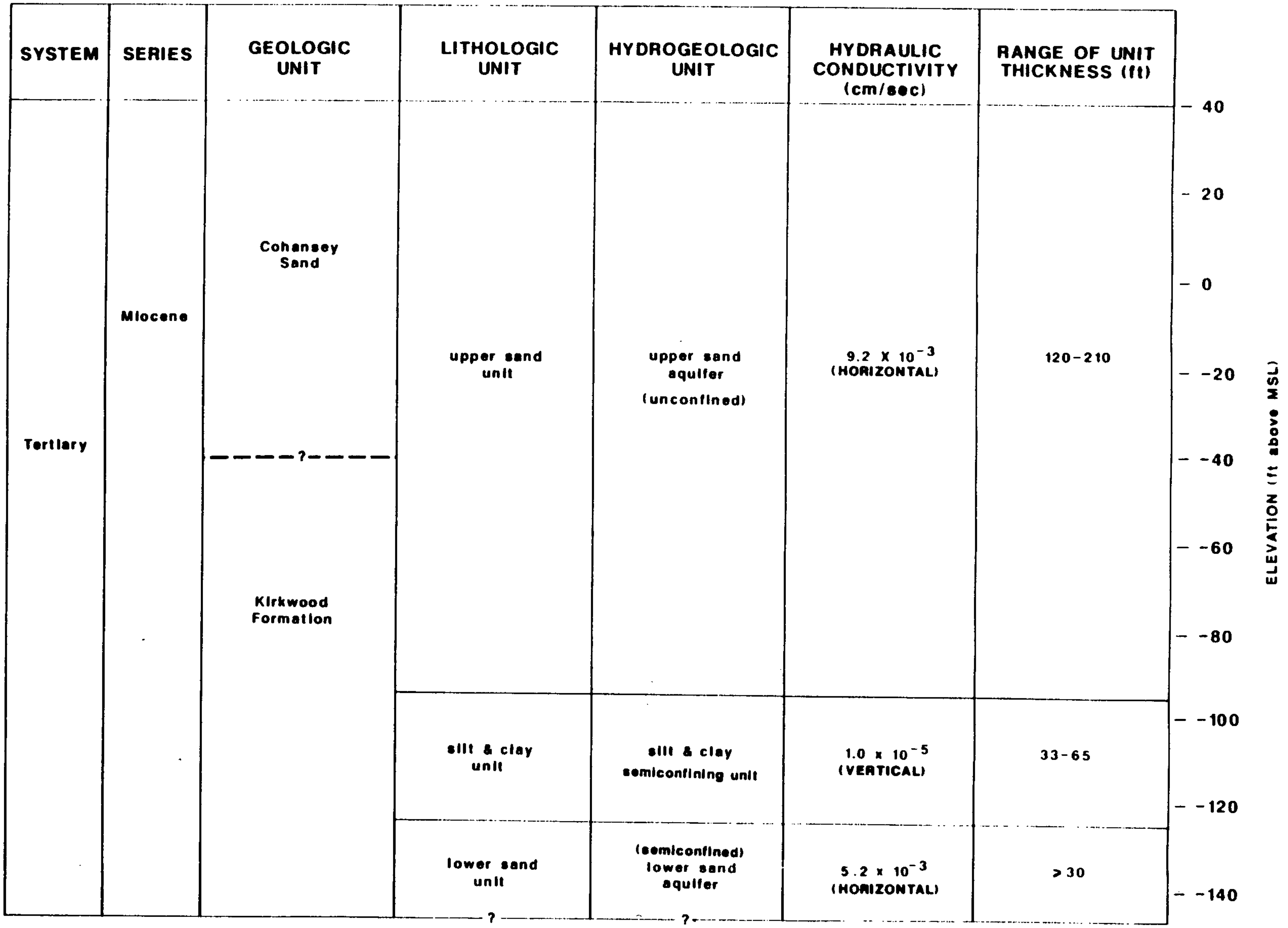
TABLE 4-7

COMPARISON OF WATER LEVEL MEASUREMENTS FROM DIFFERENT ELEVATIONS IN UPPER SAND AQUIFER, JANUARY 14, 1986

	"S" Wells					"D" Wells					
Well Location	Screen Depth		Screen Elev.		Water Level Elev.	Screen Depth		Screen Elev.		Water Level Elev.	Water Level Difference
	Top	Bottom	Top	Bottom		Top	Bottom	Top	Bottom		
1	14.00	20.00	8.80	2.80	9.63	24.00	34.00	-0.80	-10.80	9.89	-0.26
2	3.00	9.00	11.08	5.08	11.20	9.50	14.50	4.71	-0.29	11.25	-0.05
3	25.60	31.70	-5.48	-11.58	14.87	38.50	49.50	-18.29	-29.29	14.85	0.02
4	34.00	45.00	15.10	4.10	11.62	68.75	79.75	-19.34	-30.35	11.71	-0.09
5	23.88	34.88	16.07	5.07	10.67	53.25	64.25	-13.40	-24.40	12.64	-1.97*
10	28.20	34.20	-5.08	-11.08	15.94	54.00	65.00	-35.80	-41.80	15.95	-0.01
11	22.80	28.80	-1.80	-7.80	15.86	61.00	67.00	-39.82	-45.82	15.82	0.04
12	22.38	28.38	-5.12	-11.12	10.29	34.00	45.00	-16.77	-27.77	11.60	-1.31
13	14.90	20.90	-1.41	-7.41	10.63	30.20	41.20	-16.57	-27.57	12.18	-1.55
14	17.00	28.00	19.09	8.09	14.23	49.50	60.50	-13.41	-24.41	13.45	0.78
15	28.88	39.88	19.27	8.27	14.60	59.50	70.50	-10.95	-21.95	14.25	0.35
19	30.75	36.75	19.15	13.15	18.61	38.50	49.50	11.40	0.40	18.58	0.03
20	56.00	62.00	-2.03	-8.03	15.84	79.50	90.50	-25.43	-36.43	15.79	0.05
21	34.00	40.00	14.19	8.19	13.61	85.00	96.00	-36.80	-47.80	13.62	-0.01
22	40.00	46.00	15.10	9.10	17.01	59.00	70.00	-4.10	-15.10	16.99	0.02
23	68.00	74.00	-2.47	-8.47	19.12	84.50	95.50	-18.97	-29.97	19.19	-0.07
24	59.00	65.00	6.59	0.59	22.93	74.00	85.00	-8.21	-19.21	23.07	-0.14
27	49.00	55.00	10.80	4.80	23.46	89.00	100.00	-29.40	-40.40	23.30	-0.16
28	30.50	41.50	-2.00	-13.00	17.98	52.50	63.50	-23.70	-34.70	17.97	-0.01
29	27.00	33.00	-8.20	-14.20	14.90	56.48	67.48	-37.68	-48.68	15.46	-0.56
31	40.85	46.85	5.45	-0.55	19.06	78.00	89.00	-31.30	-42.30	18.69	0.37

All elevations in feet above MSL. Other measurements in feet.

*Water level differences of -0.26 ft, -0.06 ft, and 0.04 ft for 12/03/85, 01/03/86, and 02/19/86, respectively.

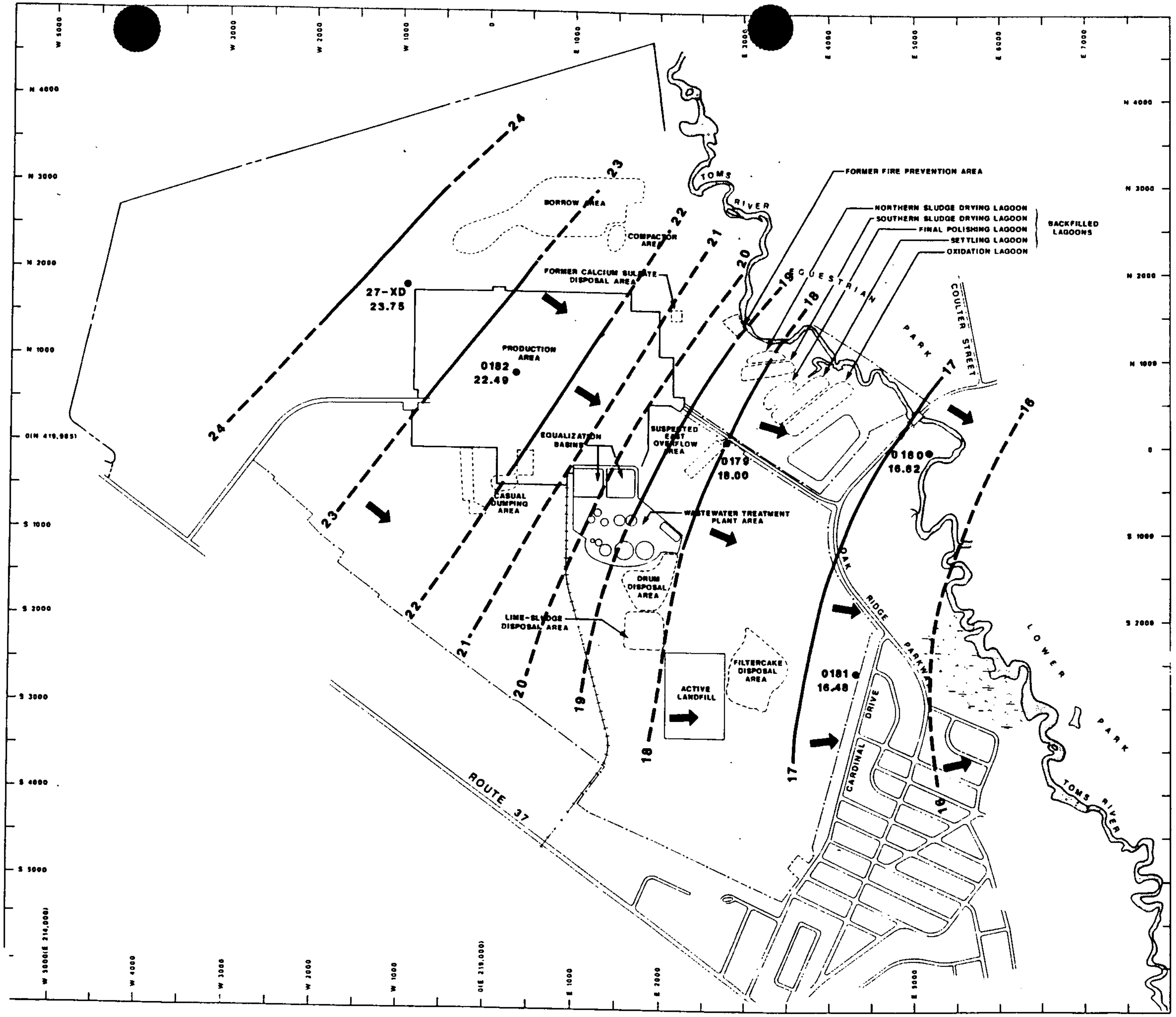


SYSTEM	SERIES	GEOLOGIC UNIT	LITHOLOGIC UNIT	HYDROGEOLOGIC UNIT	HYDRAULIC CONDUCTIVITY (cm/sec)	RANGE OF UNIT THICKNESS (ft)
Tertiary	Miocene	Cohansey Sand ? Kirkwood Formation	upper sand unit	upper sand aquifer (unconfined)	9.2×10^{-3} (HORIZONTAL)	120-210
			silt & clay unit	silt & clay semiconfining unit	1.0×10^{-5} (VERTICAL)	33-65
			lower sand unit ?	(semiconfined) lower sand aquifer ?	5.2×10^{-3} (HORIZONTAL)	> 30

CORRELATION OF LITHOLOGIC AND HYDROGEOLOGIC UNITS, CIBA-GEIGY SITE, DOVER TWP., N.J.

FIGURE 4-18

NUS CORPORATION



LOWER SAND AQUIFER PIEZOMETRIC SURFACE JANUARY 14, 1986

LEGEND

FIGURE 4-19

NUS CORPORATION

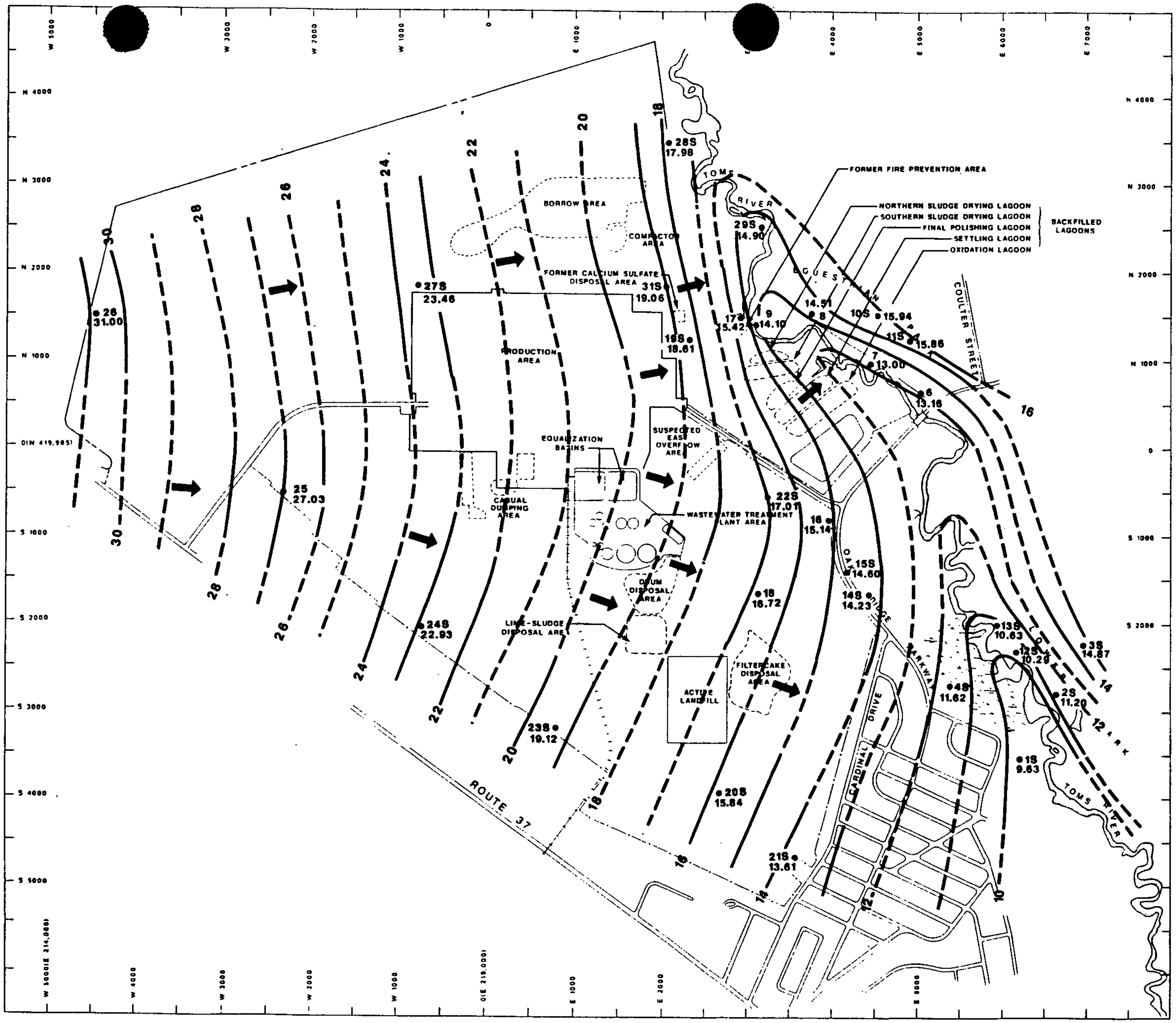
4.4.1.4 Upper Sand Aquifer

A piezometric surface of the upper sand aquifer indicates an eastward to southeastward flow across most of the site (Figure 4-20). The Toms River has a large influence on this aquifer, acting as a groundwater sink with hydraulic gradients of approximately 0.003 on either side of the main channel. The average hydraulic gradient across the site is 0.002. Assuming an average porosity for this unit of 0.4, interstitial groundwater velocity is approximately 850 feet/year beneath most of the site and 70 feet/year near the Toms River. Velocity may be significantly higher in some of the more permeable units.

The resolution of the piezometric surface is insufficient to determine groundwater flow direction close to the Toms River; strong vertical flow components near the river prohibit accurate determination of water-table elevation from monitoring wells. The role of the river itself as a barrier for all groundwater in the upper sand aquifer is questionable. This is particularly true given the high concentrations of contaminants in well RI-9 on the east side of the Toms River (see Section 4.5). The presence of a clay layer in the area of well RI-9 may also have some effect. High-density piezometer studies should be conducted to determine three-dimensional flow in the river meander at RI-9 as well as a part of the river where an underlying clay unit does not exist.

From the piezometric surface and aquifer characteristics, a daily average water budget for the upper sand aquifer is calculated (Table 4-8). The dominant source for groundwater at the site is infiltration from precipitation (Groundwater Management Planning, 1978). The 1.8×10^6 gallons/day average recharge from precipitation is slightly larger than the 1.7×10^6 gallons/day pumped by Ciba-Geigy purge wells (AWARE, 1986), the largest groundwater sink. Imbalance in the water budget may be the result of inaccuracy in estimating the average recharge rate, determined to be between approximately 15 and 20 inches/year (Groundwater Management Planning, 1978).

It is important to note that "outflow" is primarily, but may not be exclusively, groundwater entering the Toms River. It is simply an estimate of the amount of groundwater leaving the site to the east.



UPPER SAND AQUIFER PIEZOMETRIC SURFACE JANUARY 14, 1986

LEGEND

- RAILROAD SPUR
- SURVEYED BOUNDARY
- BOUNDARY FENCE
- BOUNDARY ROAD
- ➡ GROUNDWATER FLOW DIRECTION
- 22 —— 22 EQUIPOTENTIAL LINES
- 20 – – – 20 INFERRED EQUIPOTENTIAL LINES
- 24S 22.93 ● WELL LOCATION AND WATER LEVEL IN FEET MSL

FIGURE 4- 20

NUS CORPORATION

TABLE 4-8

DAILY AVERAGE WATER BUDGET FOR UPPER SAND AQUIFER AT CIBA-GEIGY TOMS RIVER PLANT

VALUES USED		
Area		
Surface	6.1×10^{7} ft^2	
Recharge (Infiltration)	5.8×10^{7} ft^2	
Vertical inflow (from silt and clay semiconfining unit)	3.4×10^{7} ft^2	
Vertical outflow (to silt and clay semiconfining unit)	2.7×10^{7} ft^2	
Inflow X-section	378,000 ft^2	(4,200 ft x 90 ft)
Outflow X-section	768,000 ft^2	(9,600 ft x 80 ft)
Gradient		
Lateral inflow	0.002	
Lateral outflow	0.003	
Vertical inflow	0.05	(3 ft/60 ft)
Vertical outflow	0.05	(2 ft/40 ft)
Hydraulic Conductivity		
Upper sand aquifer (Horizontal)	9.2×10^{-3} cm/sec	(2.6×10^{1} ft/day)
Silt and clay unit (Vertical)	1.0×10^{-5} cm/sec	(2.8×10^{-2} ft/day)
Recharge (Infiltration) Rate	18 in./year	(4.11×10^{-3} ft/day)

SOURCES

Inflow

= Horizontal Conductivity x Inflow Gradient x Inflow X-section Area

= 2.6×10^{1} ft/day x 0.002x378,000 ft^2

= 1.5×10^{5} gallons/day

TABLE 4-8 (CONT'D)
DAILY AVERAGE WATER BUDGET FOR UPPER SAND AQUIFER AT CIBA-GEIGY TOMS RIVER PLANT

Recharge (Infiltration)

= Infiltration Rate x Recharge (Infiltration) Area
= 18 in./year x 5.8×10^7 ft^2
= 1.8×10^6 gallons/day

Vertical inflow (from silt and clay semiconfining unit)

= Vertical Conductivity x Vertical Recharge Gradient x Recharge Area
= 2.8×10^{-2} ft/day x $0.05 \times 3.4 \times 10^7$ ft^2
= 3.6×10^5 gallons/day

Sum of Sources	=	2.3×10^6 gallons/day

SINKS

Outflow

= Horizontal Conductivity x Outflow Gradient x Outflow X-section Area
= 2.6×10^1 ft/day x $0.003 \times 768{,}000$ ft^2
= 4.5×10^5 gallons/day

Vertical outflow (to silt and clay semiconfining unit)

= Vertical Conductivity x Vertical Discharge Gradient x Discharge Area
= 2.8×10^{-2} ft/day x 0.05 x 2.7×10^7 ft^2
= 2.8×10^5 gallons/day

Purge Wells	=	1.7×10^6 gallons/day
Sum of Sinks	=	2.4×10^6 gallons/day

Sum of Sources/Sum of Sinks	=	96%

4.4.2 Contaminant Migration Potential

This section outlines factors influencing migration of contaminants in groundwater, particularly waste characteristics and groundwater flow direction.

4.4.2.1 Waste Characteristics

Groundwater flow direction is useful only for characterization of potential aqueous phase contaminant migration. Nonaqueous phase liquids (NAPLs) migrate according to geology and gravity and therefore tend to accumulate above less permeable lithologic units. Suspected NAPLs were found in well 0111 near the Drum Disposal Area. However, the extremely high concentrations of dissolved organic contaminants commonly associated with NAPL plumes have not been detected in surrounding wells. Therefore if NAPL does occur at this site it does not appear to be widespread; however, additional investigation is necessary.

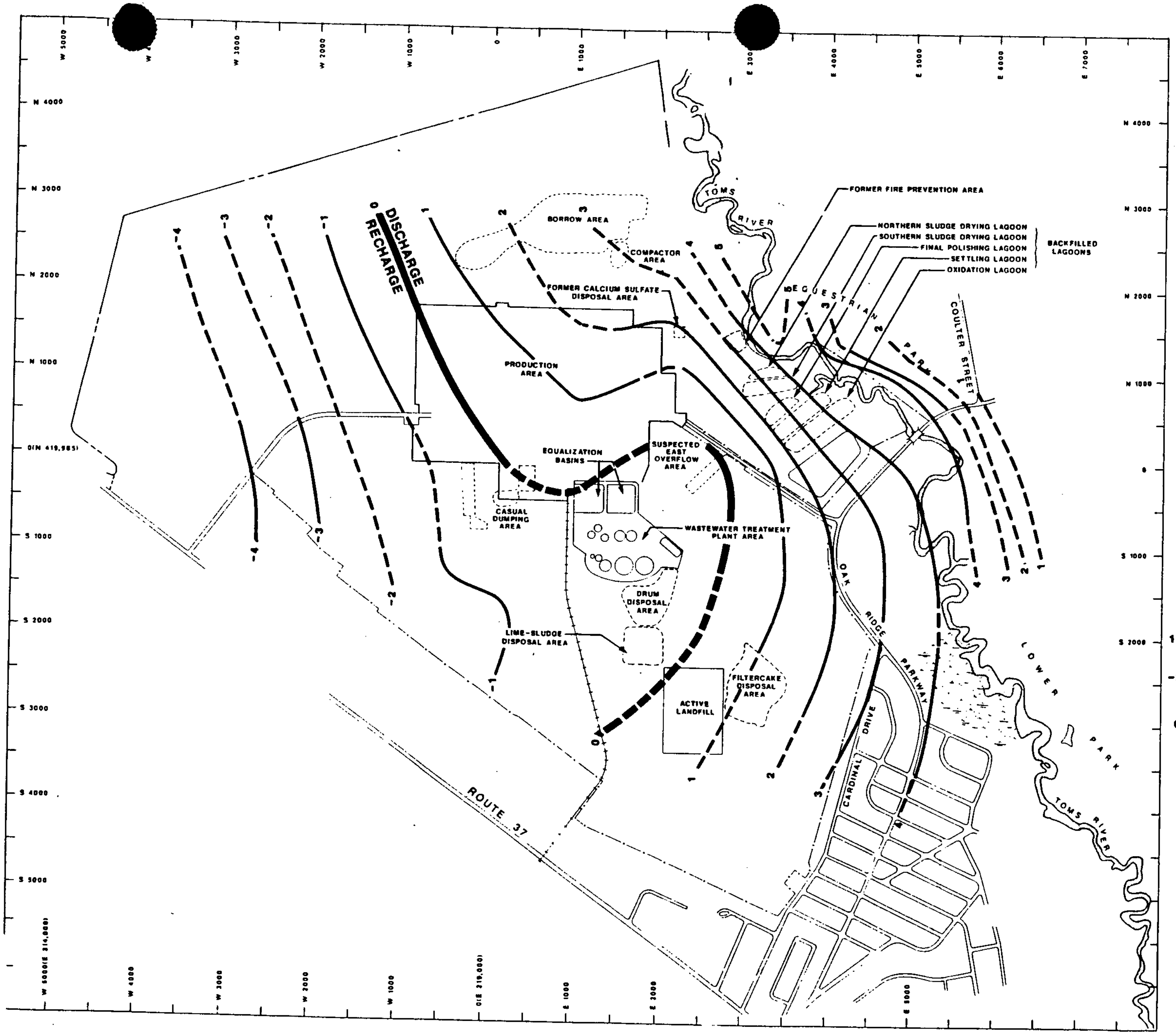
4.4.2.2 Migration Under Present Groundwater Flow

Unconfined Upper Sand Aquifer

Under the flow conditions shown for January 14, 1986, groundwater flow would carry contaminants from the Production Area, Equalization Basins, or Drum Disposal Area southeast or east toward the Toms River. Contaminants from the Backfilled Lagoons Area would migrate northeastward before discharging into the river.

Semiconfined Lower Sand Aquifer

A downward hydraulic gradient exists across much of the site between the upper sand aquifer and the lower sand aquifer (Figure 4-21). Where this downward gradient exists, contaminants can potentially migrate into the lower sand aquifer



DIFFERENTIAL HEAD BETWEEN LOWER AQUIFER AND UPPER SAND AQUIFER JANUARY 14, 1986

LEGEND

—+—+— RAILROAD SPUR
—·—·— SURVEYED BOUNDARY
—··—··— BOUNDARY FENCE
- - - - - - BOUNDARY ROAD
1 ——— 1 ISOPLETH OF DIFFERENTIAL HEAD, IN FEET
-2 — — — -2 INFERRED ISOPLETH OF DIFFERENTIAL HEAD, IN FEET
0 ▬▬▬ 0 DISCHARGE/RECHARGE BOUNDARY (DISCHARGE TO LOWER SAND AQUIFER,RECHARGE TO UPPER SAND AQUIFER)

FIGURE 4-21

NUS CORPORATION

where they can be carried southeastward past the Toms River. The average time for contaminants to migrate through the silt and clay semiconfining unit into the gray-brown sand can be calculated by the following formula:

$$t = \frac{L^2 n}{K \quad H}$$

Where: t = time for contaminant to migrate through a unit
n = effective porosity
K = vertical hydraulic conductivity
H = difference in hydraulic head
L = thickness of the silt and clay semiconfining unit

Given $n = 0.4$, $K = 1.0 \times 10^{-5}$ cm/sec (0.028 ft/day), $H = 2$ ft, and $L = 40$ ft, the average time necessary for contaminants to migrate through the silt and clay confining unit is approximately 31 years.

4.4.2.3 Natural Variations

Fluctuations in precipitation will have by far the greatest effect on groundwater flow of any natural controls. Precipitation affects infiltration, changing the water-table elevation and hydraulic gradients, particularly near the Toms River. Also affected is the head differential between the upper sand aquifer and the lower sand aquifer. However, the greatest change in aquifer behavior occurs when rapid runoff causes the Toms River to flood. At flood stage, the normally effluent Toms River can discharge water to the upper sand aquifer, causing bank storage. These periods may be critical in causing contaminant migration to the east side of the river. The normally steep hydraulic gradient along the river is reduced or even reversed. In a situation where relatively high head exists on the west side of the river, contaminants could get pushed under the influent stream to the east side.

Because bank storage is a temporary phenomenon, contaminated groundwater pushed from the west side would not be expected to travel far and would probably discharge into the river eventually. However, residual contamination could remain for long periods of time.

4.4.2.4 Artificial Variations

Lagoons

Although considerable effort has been spent modeling contaminant migration under current groundwater flow patterns, contaminants may have been introduced into the groundwater system under a different flow regime. The old wastewater treatment plant used unlined lagoons for disposal from 1952 to 1977 (see Section 3.5). The five lagoons, which have since been backfilled, had a combined area of approximately 371,400 ft^2 and bottomed between +20 and +21 feet above MSL when they were closed. Sludge has been found at depths as low as +13 feet MSL in borehole RI-A-5.

The influence of these lagoons on groundwater flow would have depended on water elevations in the lagoons and permeability of the lagoon bottom. A significant discharge of water from the lagoons would cause the following:

- Radial or semiradial flow patterns away from the lagoons. This would result in significant northward and southward flow components not present at the site today.
- A steeper hydraulic gradient between lagoons and the Toms River.
- Possible reduction of hydraulic gradient on the opposite side of the river.
- Change in differential head between the upper sand aquifer and the lower sand unit. Increased head in the upper sand aquifer would extend the area where it recharges the lower sand aquifer. This could facilitate transport of contaminants through the silt and clay semiconfining unit into the underlying aquifer.

Combined with complexities of a clay layer extending under and beyond the lagoon area, some contaminants could migrate beneath the main river channel, eventually discharging farther downstream from the east side of the river.

Purge Wells

In January 1985, Ciba-Geigy began utilizing a purge-well system to intercept contaminated groundwater migrating toward the Cardinal Drive residential area. The 5-well system is reported to pump 1.7 million gallons per day from the upper sand aquifer (AWARE, 1986). The effectiveness of the system is evaluated by analysis of groundwater flow patterns determined from a piezometric surface, and extent of the contaminant plume.

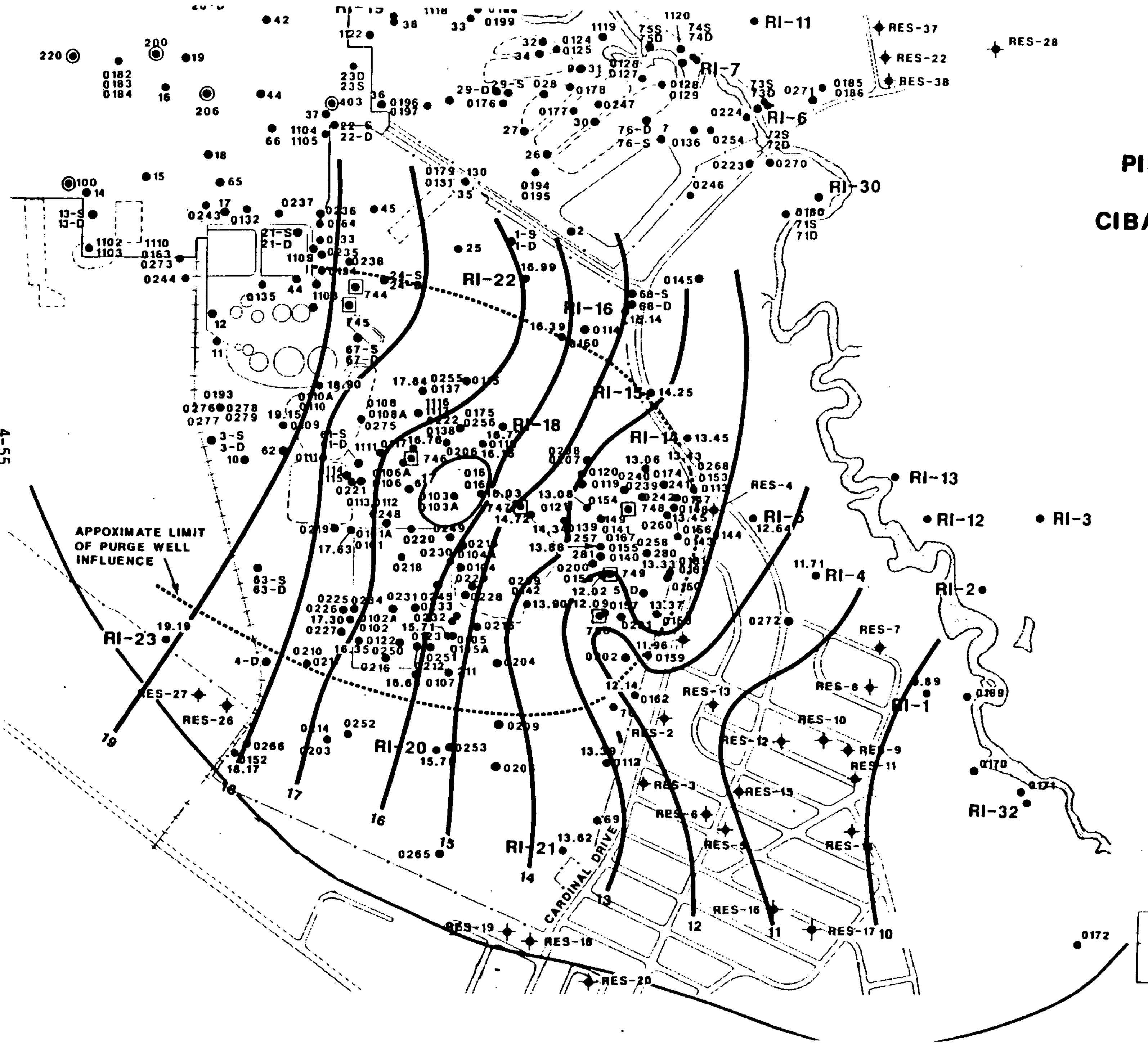
A piezometric surface for January 14-16, 1986, is shown in Figure 4-22 from water-level measurements reported by AWARE (Appendix D-5) and NUS. While the effect of the purge wells on groundwater flow is apparent, the limit of purge-well influence does not extend into the Cardinal Drive residential area. As a result, contaminated groundwater can flow into the area from north or south of the limit of influence. While intercepting much of the contaminated groundwater in the area, the purge wells also serve to divert potentially contaminated groundwater from the Southeast Production Area into the residential area.

One additional effect of the purge wells is to reduce the amount of water in the upper sand aquifer, thus causing an upward gradient from the lower sand aquifer. While this serves to reduce the potential for contaminants to penetrate the silt and clay semiconfining unit, the purge well influence must be subtracted from any model of contaminant migration prior to 1985.

4.5 Groundwater Quality Investigation

Section 4.5 discusses the groundwater quality investigation performed by NUS Corporation at the Ciba-Geigy Site.

PIEZOMETRIC SURFACE IN VICINITY OF CIBA-GEIGY PURGE WELLS



LEGEND :

▬	EQUIPOTENTIAL LINE
	RAILROAD SPUR
	SURVEYED BOUNDARY
	BOUNDARY FENCE
	BOUNDARY ROAD
	APPROXIMATE LATERAL EXTENT OF CONTAMINATION
●RI-12S	EPA MONITORING WELL
0126	CIBA-GEIGY MONITORING WELL OR PIEZOMETER
●	CIBA-GEIGY PRODUCTION WELL
⊞	CIBA-GEIGY PURGING WELL
✦	RESIDENTIAL WELL

FIGURE 4-22

NUS CORPORATION

The objectives of this investigation were to

- Identify source areas
- Determine the extent of groundwater contamination associated with source areas
- Determine health risks associated with groundwater contamination

Sections 4.5.1, 4.5.2, and 4.5.3 discuss the methods, results, and conclusions of this investigation.

4.5.1 Methods of Groundwater Quality Investigation

Three methods were used to achieve the objectives of the groundwater quality investigation 1) GPR was used to identify source areas, 2) EM was used to determine the magnitude of source area contamination and extent of contamination, 3) Groundwater sampling and analysis was used to determine the extent of contamination, source area contamination, and health risks associated with contamination. These methods are discussed in Sections 4.5.1.1, and 4.5.1.2, and 4.5.1.3.

4.5.1.1 Methods and Locations of the Ground Penetrating Radar Investigation

GPR was used to locate and characterize potential contaminant source areas as either point source anomalies (drums) or layered anomalies (landfilled areas). Six potential contaminant source areas were selected for GPR profiling based on previous investigations and historical air-photographs. Background information included the Remedial Action Master Plan by Clement Associates (1983), Ciba-Geigy hydrogeological investigations by Geonics (1980-1982), historical aerial-photographs supplied by EPA, and some initial RI borehole drilling data. After profiling, data were analyzed to estimate the lateral and vertical extent of waste or disturbed areas. This analysis was conducted for the effective positioning of boreholes, waste volumetric calculations, and reduction of the risk involved in drilling through waste.

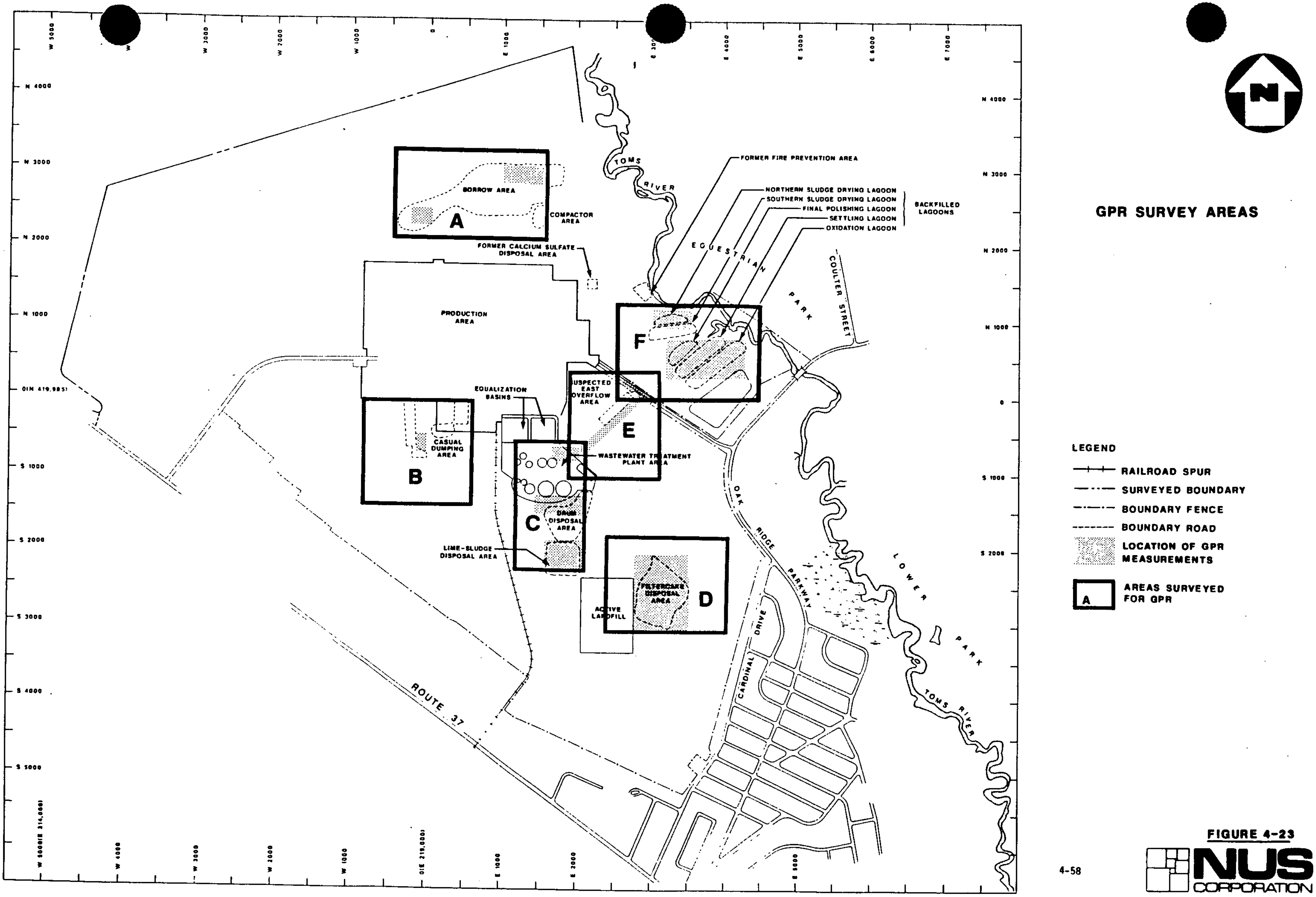
To conduct the survey, Weston Geophysical Corporation (WGC) used a Subsurface Interface Radar (SIR) System, Model 8, coupled with a 300 MHz antenna. This instrument is capable of penetrating to a depth of approximately 15 feet producing a cross section representing the reflective characteristics of subsurface units in the surveyed area. Materials of different physical characteristics, particularly density, will respond differently and will be reproduced on the GPR cross section as light or dark images or bands.

Within the 6 potential source areas, 10 GPR survey sites were located and investigated (Figure 4-23). The potential source areas are the Borrow Area, the Casual Dumping Area, Drum Disposal Area/Lime Sludge Disposal Area, Filtercake Disposal Area, Suspected East Overflow Area, and the Backfilled Lagoons Area. Each potential source area was investigated by pulling the GPR antenna over parallel or intersecting survey lines, depending on topography and ground cover.

4.5.1.2 Methods and Locations of the Electromagnetic Conductivity Investigation

The electromagnetic conductivity survey was conducted to provide insight into the lateral and vertical extent of groundwater contamination, to provide additional information on the GPR investigation areas, and to expand the existing Ciba-Geigy EM data base.

Electromagnetic conductivity data are a generally accepted means of mapping soils, bedrock, groundwater, and contaminant plumes. For the purposes of the RI, the EM technique was used initially as a screening technique for monitoring well placement within a potential contaminant plume (an EM high). It was later used to define the plume with the corroboration of total volatile priority pollutant concentrations and groundwater specific conductance.



GPR SURVEY AREAS

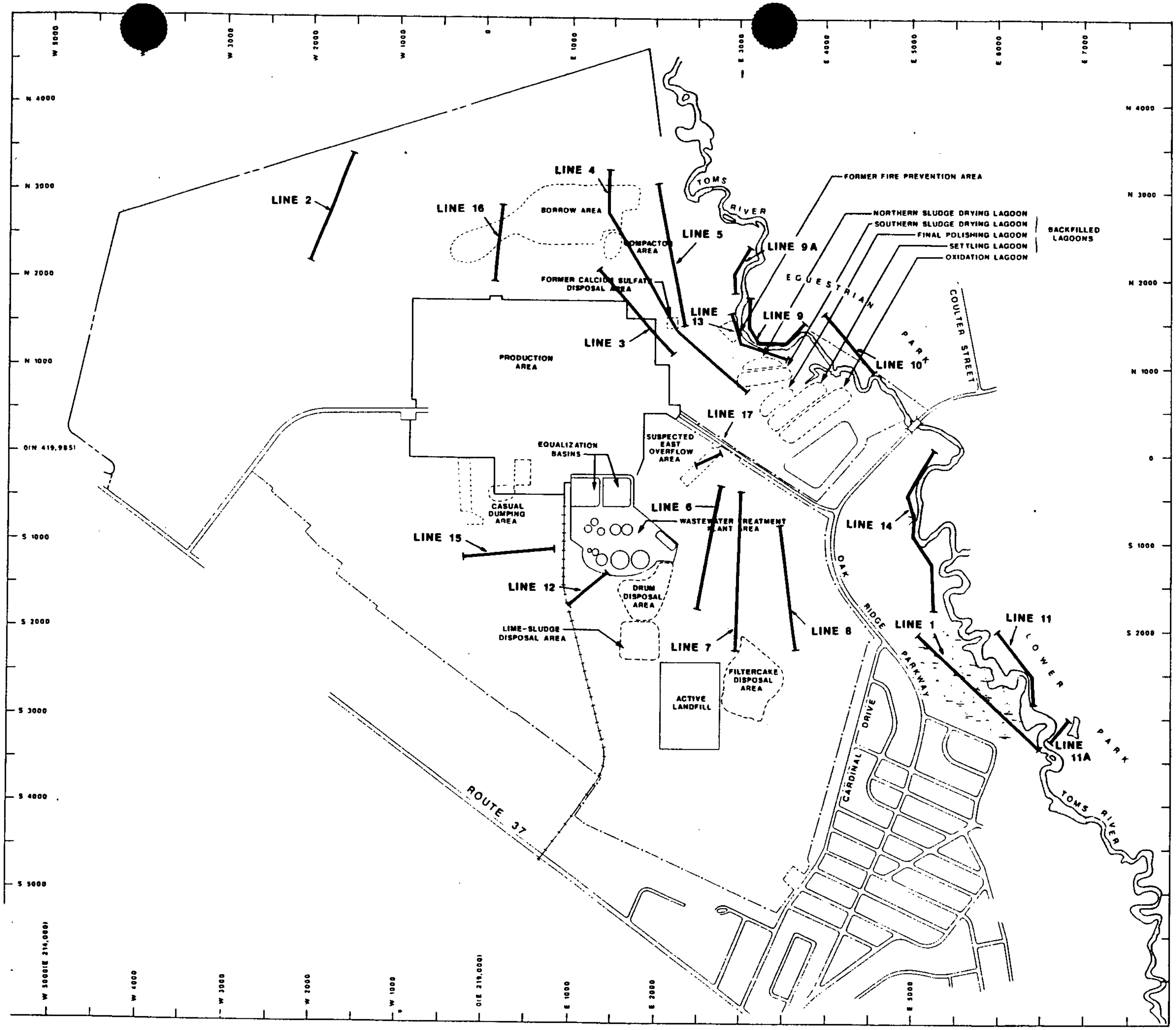
FIGURE 4-23

NUS CORPORATION

The instrument used was the Geonics EM-34-3 noncontacting terrain conductivity meter. Measurements were taken in horizontal and vertical dipole modes with 25-foot spacing. The two dipole orientations are used to concentrate on different depths of investigation. Nineteen EM data lines were surveyed on the Ciba-Geigy Site and off-site areas adjacent to the Toms River (Figure 4-24). The horizontal dipole method (HDM) of data collection was used on lines 1, 9, 9A, 10, 11, 11A, 13, 14, 15, 16, and 17. This method was used because of line location with respect to potential contaminant source areas and shallow groundwater. The shallow depth of penetration of this method (less than 50 feet) is ideal to investigate these areas because of the probability of drums and waste being buried at depths shallower than 50 feet. The vertical dipole method (VDM) of data collection was used on lines 2 through 10, and 15 through 17. The vertical dipole method with its greater depth of penetration (approximately 100 feet) was used to investigate the areal extent of the contaminant plume.

4.5.1.3 Description of the Groundwater Sampling Events

Groundwater investigations discussed in this section were conducted by NUS Corporation Region 2 FIT and AWARE, Inc.. Fifty-nine NUS/EPA monitoring wells were constructed between February and October 1985. These wells were constructed of stainless steel inner casing 4 inches in diameter (Figure 4-25). The outer casings in all monitoring wells was at least 8 inches in diameter. Wire wound stainless steel well screens were used. The annulus was filled with a sand pack surrounding the screen to a point approximately two feet above the screen. The sand pack was then overlain with bentonite pellets and a cement/bentonite slurry. A concrete seal with a steel cap and lock was installed. Drilling methods varied due to different lithologic characteristics. These methods were mainly mud rotary and hollow stem auger. The existing well array is such that groundwater in proximity to potential source areas is monitored by Ciba-Geigy wells. These wells have provided invaluable data for identifying sources of contamination. Upgradient and downgradient wells installed by NUS have enabled characterization of groundwater quality beyond the site boundaries, particularly in the vicinity of the Toms River.



ELECTROMAGNETIC CONDUCTIVITY SURVEY LINE LOCATIONS

LEGEND

- RAILROAD SPUR
- SURVEYED BOUNDARY
- BOUNDARY FENCE
- BOUNDARY ROAD
- SURVEY LINE

FIGURE 4-24

NUS CORPORATION

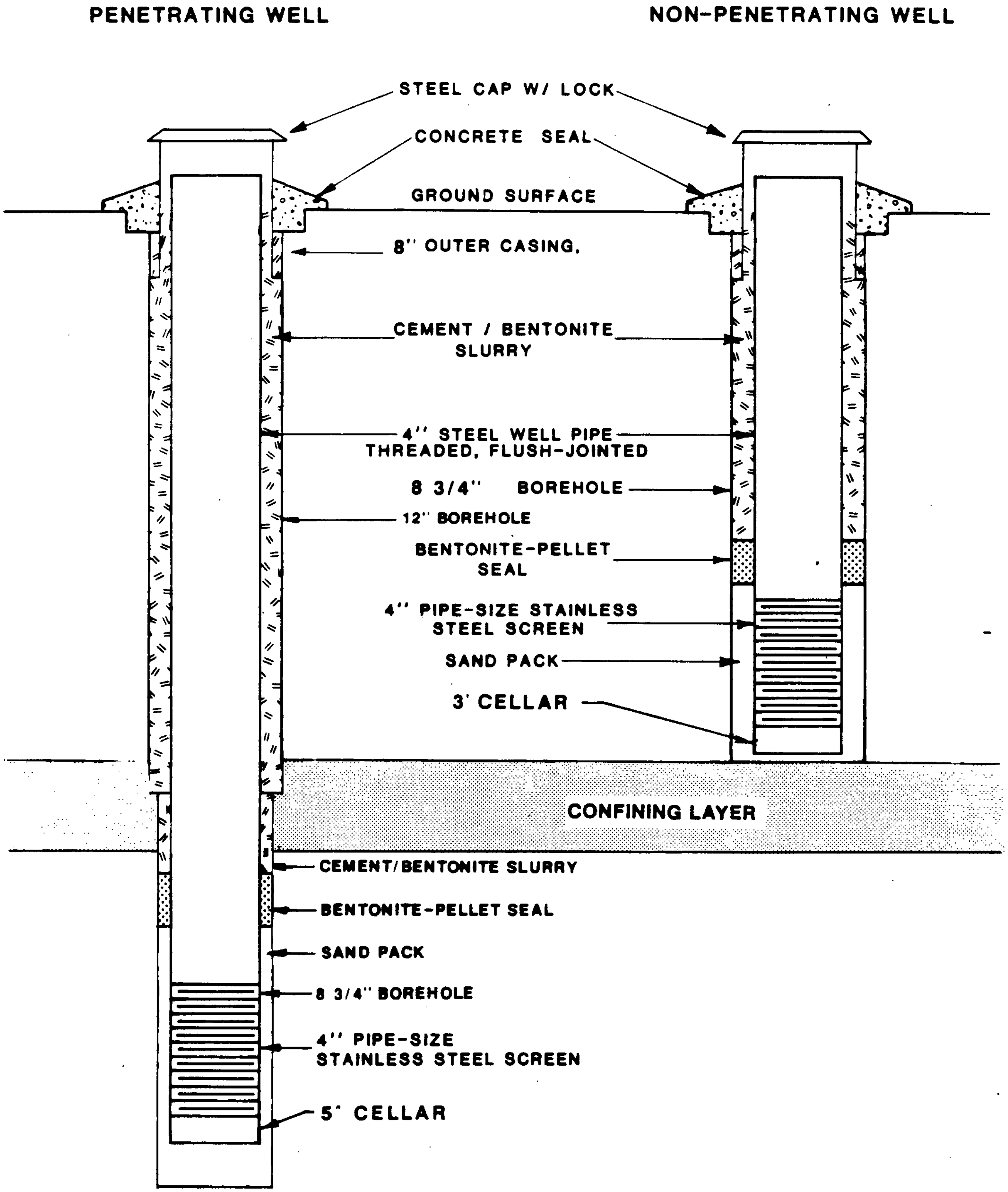


FIGURE 4-25

SCHEMATIC MONITORING WELL CONSTRUCTION

CIBA-GEIGY, DOVER TWP., N.J.

(NOT TO SCALE)

NUS CORPORATION

Groundwater from the 59 NUS/EPA monitoring wells and selected Ciba-Geigy wells was sampled and analyzed in August and October of 1985. Thirty-three wells were then selected for sampling on a quarterly basis. These wells were sampled and analyzed in August 1985, October 1985, February 1986, June 1986, and September 1986. Groundwater analyses from Ciba-Geigy wells provided by AWARE, Inc., supplemented the NUS monitoring program. AWARE subcontracted SR Analytical of Cherry Hill, New Jersey to perform the analyses on samples collected in September 1985, January 1986, and April 1986. In addition, split samples of groundwater from NUS wells and selected Ciba-Geigy wells were collected by AWARE. The analytical results of the sampling events are presented in Appendices A-1 and A-2. Appendix A-1 contains data from groundwater sampling events conducted by NUS; these events are NUS 1 through NUS 6, and NUS 25. Appendix A-2 contains data from sampling events conducted by AWARE. Their sampling events are TRC 1 through TRC 35.

Due to the variety of contaminants associated with the site and the large number of samples collected, a contamination indicator is required to help determine trends. Total Volatile Priority Pollutants (TVPP) was chosen as the most representative indicator (Table 4-9). Volatile priority pollutants with concentrations below contract-specified detection limits were not included. Those compounds not used as contamination indicators and the reasons for their exclusion are as follows:

- Pesticides and PCBs were detected in only one sampling event, NUS 2, and were not tested for in many of the other sampling events.

- Inorganic background concentrations are often higher than contaminant concentrations. Background concentrations for many inorganic contaminants are 1000 ug/L or higher, whereas concentrations for volatile contaminants may be as little as 1 ug/L. Therefore, inclusion of inorganic concentrations could mask the contaminant concentration.

TABLE 4-9
CONTAMINANTS INCLUDED IN TVPP SUMMATION

Acenaphthene
Acetone
Azobenzene
Benzene
Benzoic Acid
Benzyl Alcohol
Bis(2-Chloroethyl) ether
Bis(2-Ethylhexyl) phthalate
Bromodichloromethane
2-Butanone
Carbon disulfide
4-Chloroaniline
Chlorobenzene
Chloroform
Chloromethane
2-Chloronaphthalene
2-Chlorophenol
Di-n-octyl phthalate
1,2-Dichlorobenzene
1,3-Dichlorobenzene
1,4-Dichlorobenzene
1,1-Dichloroethane
1,2-Dichloroethane
1,1-Dichloroethene
trans-1,2-Dichloroethene
2,4-Dinitrotoluene
1,2-Dichloropropane
Ethylbenzene
Fluorene
2-Hexanone
Methylene chloride
4-Methylphenol
4-Methyl-2-pentanone
Naphthalene
4-Nitroaniline
Nitrobenzene
4-Nitrophenol
N-Nitrosodimethylamine
Pentachlorophenol
Phenol
Pyrene
1,1,2,2-Tetrachloroethane
Tetrachloroethene
Toluene
Total Xylenes
1,2,4-Trichlorobenzene
1,1,1-Trichloroethane
Trichloroethene
Vinyl chloride

Total Volatile Priority Pollutants (TVPPs) were calculated by adding the concentrations of the above contaminants. Those contaminants with concentrations below detection limits were considered to have a concentration of zero.

- Not all volatile organic chemicals were analyzed for; because the data base was insufficient to generate a total of all volatile chemicals, TVPP were used as an indicator.

- An individual chemical could not be chosen as the indicator of contamination because one chemical is not found associated with all contamination on site. Also, many chemicals tend to either float or sink in a water column, and therefore, a single indicator chemical may be detected only in wells that are screened at a particular depth.

- Compounds found in laboratory or rinsate blanks were excluded from TVPP calculations.

Inorganic concentrations above background were determined by comparisons with maximum contamination levels (MCLs) published in Code of Federal Regulations (40 CFR, Ch. 1, S141.13, July 1, 1986).

4.5.2 Results of the Groundwater Quality Investigation

This section summarizes the GPR, EM, and groundwater sampling investigations.

4.5.2.1 Ground Penetrating Radar Survey Results

The results of the GPR profiling at each area of investigation are provided in the following paragraphs. Figure 4-23 illustrated the areas and sites of the investigation.

Borrow Area (Area A)

Two areas were investigated in the Borrow Area (Appendix D-1, Figure 3). Subsurface soil disturbance is indicated in the southwestern area. At this location several potential point sources were identified at approximately 3 to 6 feet below ground surface.

Casual Dumping Area (Area B)

A layer of disturbed soil ranging in depth from 4 feet to a maximum of 12 feet was identified in the Casual Dumping Area. Several potential point source reflectors were identified within this layer of disturbed soil (Appendix D-1, Figure 4).

Drum Disposal Area and the Lime Sludge Disposal Area (Area C)

Two point source reflectors were identified within an apparently mottled and sometimes discontinuous background reflector in the southern part of the Drum Disposal Area, possibly delineating the limits of a single disposal pit.

The lateral subsurface limits of the Lime Sludge Disposal Area were determined. The southern end of the Lime Sludge Disposal Area is approximately 10 feet deep, while the center zone at this location is only 4 to 5 feet in depth (Appendix D-1, Figure 5).

Filtercake Disposal Area (Area D)

GPR penetration was limited in the Filtercake Disposal Area because of a near-surface conductive layer which may have been used for capping. However, several pits were detected, along with several possible point source reflectors at a depth of 2 to 6 feet (Appendix D-1, Figure 6).

Suspected East Overflow Area (Area E)

In the Suspected East Overflow Area GPR located the ocean outfall pipe trench and determined its approximate dimensions: 60 feet in width and 14 feet in depth. Reflectors observed were determined to be the limits of the trench or the pipe itself (Appendix D-1, Figure 7).

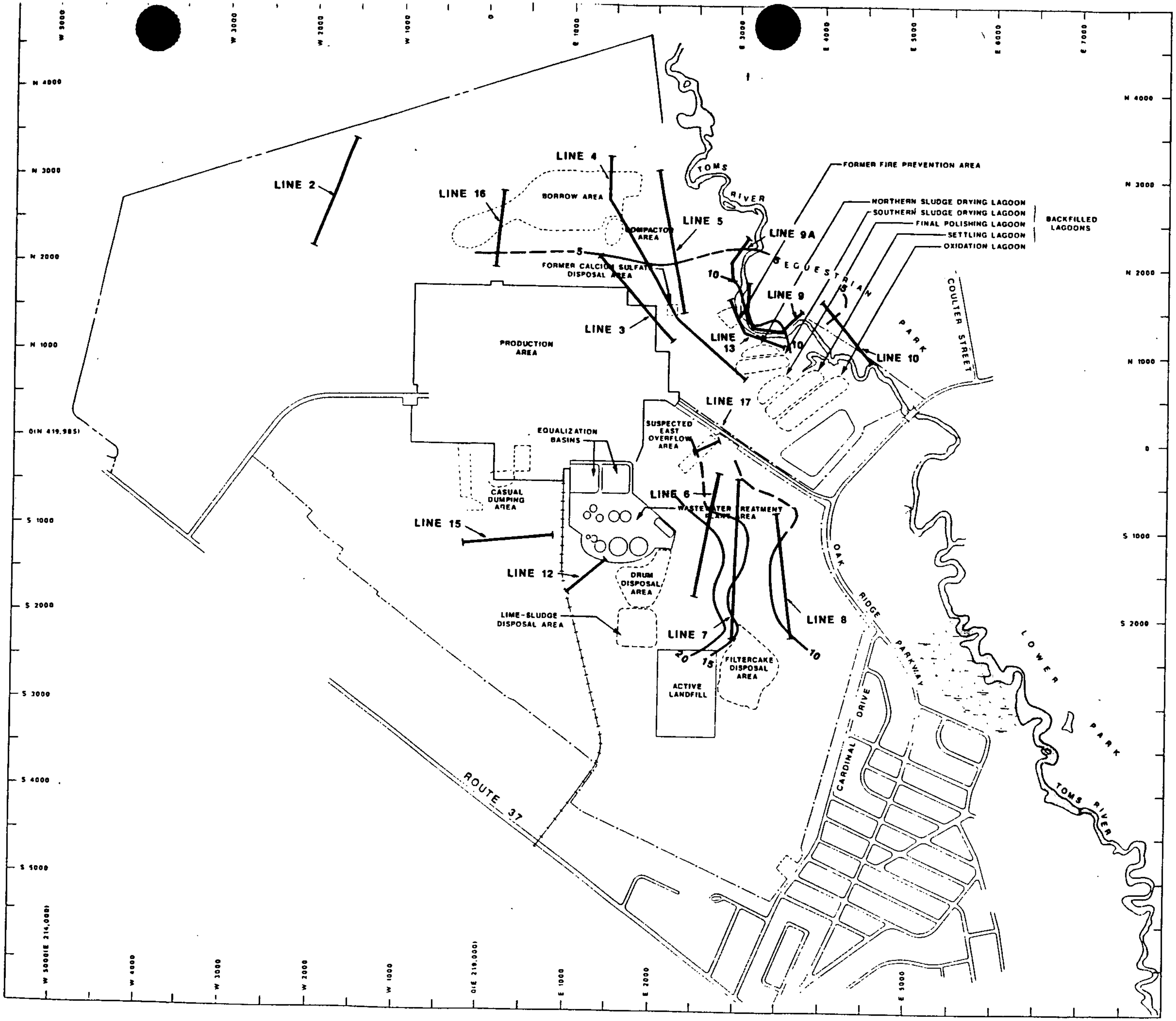
Backfilled Lagoons - Backfilled Aeration Basins and Sand Drying Beds (Area F)

The Backfilled Lagoons Area includes the backfilled aeration basins and sand drying beds. The former aeration basins contained numerous potential point source reflectors at depths of 2 to 12 feet. GPR was able to delineate the former basins and drying beds by strong bottom reflectors. Within the drying beds, GPR had limited penetration due to the high reflectivity of the bottom of the bed located 2 to 6 feet below the surface. However, several potential point source reflectors were detected between depths of 2 and 3 feet below the surface (Appendix D-1, Figure 8).

4.5.2.2 Electromagnetic Conductivity Survey Results

The results of the vertical dipole method (VDM) and the horizontal dipole method (HDM) are shown as contours of electromagnetic conductivity (Figures 4-26 and 4-27). The contours are derived by results collected by WGC (Appendix D-1, Figures 10 through 15). Measurements below 5 millimhos/meter (mmhos/m) are considered normal background by WGC and result from a thickness of poorly conductive materials in their natural state. Measurements exceeding 5 mmhos/m are considered anomalous and the result of either highly conductive natural materials or contaminants in the form of solid waste or aqueous solutions. The two methods for using EM equipment are verical dipole method (VDM) and horizontal dipole method (HDM). The vertical dipole method produces data that are representative of conductivity to a depth of 100 ft below ground level. The horizontal dipole method produces data that are representative of conductivities to a depth of 50 ft below ground level.

The EM data revealed three areas where conductivity suggests groundwater contamination.



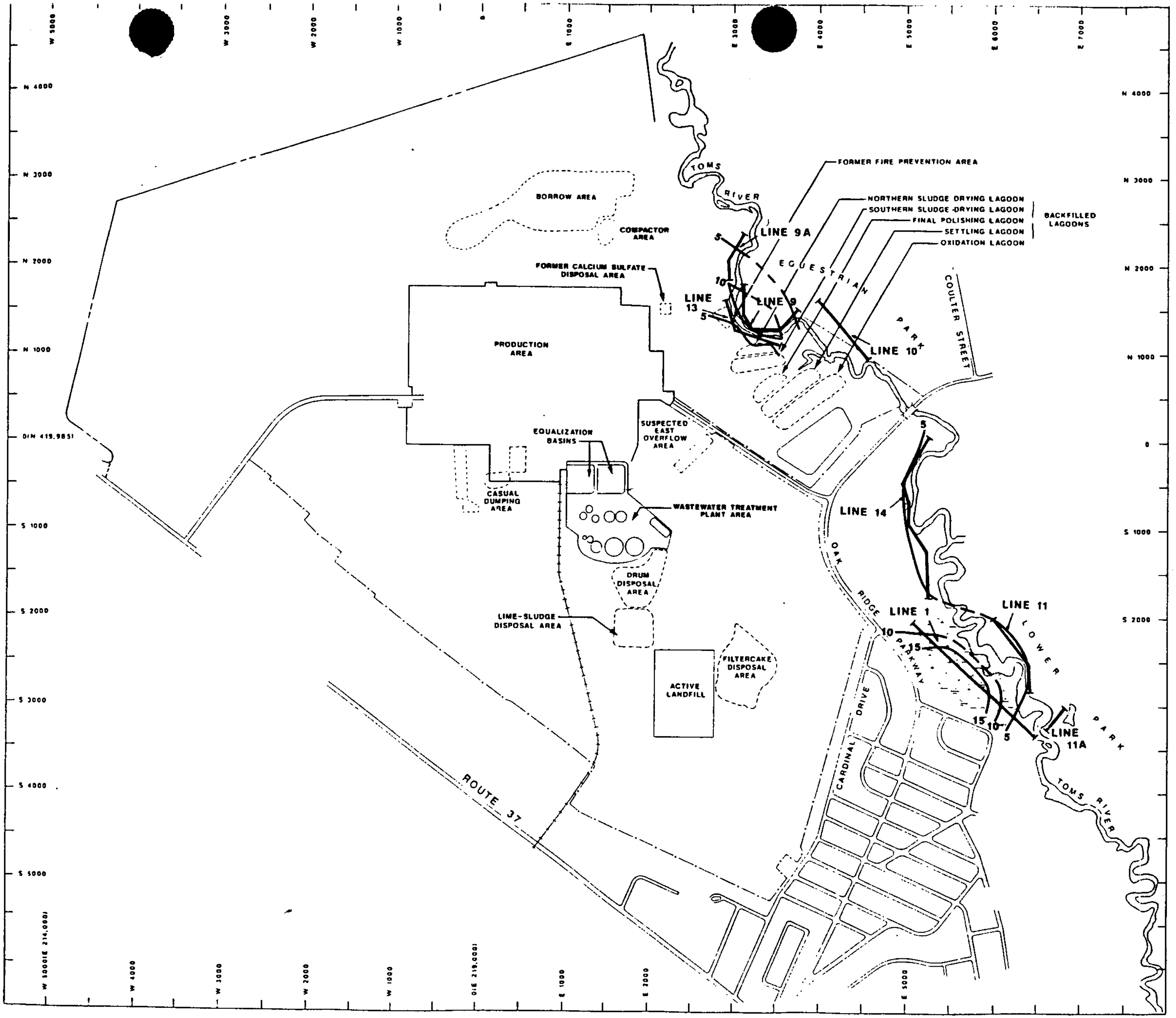
VERTICAL DIPOLE ELECTROMAGNETIC CONDUCTIVITY CONTOURS

LEGEND

- RAILROAD SPUR
- SURVEYED BOUNDARY
- BOUNDARY FENCE
- BOUNDARY ROAD
- ELECTROMAGNETIC SURVEY LINE
- 5 CONTOUR INTERVAL 5 MILLIMHOS/M

FIGURE 4-26

NUS CORPORATION



HORIZONTAL DIPOLE ELECTROMAGNETIC CONDUCTIVITY CONTOURS

LEGEND

- ┼─┼─┼ RAILROAD SPUR
- —··— SURVEYED BOUNDARY
- —·— BOUNDARY FENCE
- ------- BOUNDARY ROAD
- ┣━━┫ ELECTROMAGNETIC SURVEY LINE
- 5─── CONTOUR INTERVAL 5 MILLIMHOS/M

FIGURE 4-27

NUS CORPORATION

Backfilled Lagoons Area

North of the backfilled lagoons on both the eastern and western banks of Toms River is an area where conductance is elevated to 10 millimhos/m. This area extends from the Northern Sludge Drying Lagoon north along Toms River approximately 1500 feet and east of Toms River 500 feet. Both VDM and HDM had similar reading which suggests that the contamination is evenly distributed through the 50 ft depth down to 100 ft in depth (Figures 4-26 and 4-27).

Southeast of Production Area

The area southeast of the Production Area and east of the WWTP, the Drum Disposal Area/Lime Sludge Area, and the Filtercake Area is another area where elevated conductance occurs. VDM data acquired in this area suggests that contamination is at least 100 ft deep (Figure 4-26).

Marshland Area

The marsh north of the Cardinal Drive residential area has a zone of conductances above background which extends approximately 1500 feet along Toms River, 250 feet east of the river and west to the Oak Ridge Parkway (Figure 4-27). The high levels of conductance measued by the HDM data (15 mmhos/m) suggest that contamination extends at least 50 ft below the ground surface. No VDM data was collected in this area.

A zone of elevated conductivity was measured along the eastern portion of the Ciba-Geigy Site extending south from the Compactor Area to the Filtercake Disposal Area and east from the Compactor Area to the Toms River (Figure 4-26). The zone extends east of the river at several locations near monitoring wells RI-9 and RI-12. At the time of this study, the limits of the zone of elevated conductivity were well established with the exception of the RI-9 location and the southernmost boundary just north of the Filtercake Area. At the RI-9 location, the zone extends beyond the EM study area; therefore, closure of the 5 mmhos/m contour around the RI-9 location is interpolated. The southern limit of the elevated conductivity zone probably extends south of line 8, but its position cannot be reasonably estimated with existing EM data.

4.5.2.3 Groundwater Sampling Results

Due to the large amount of data for each sample and to the number of samples, the analysis of sampling results for the inorganic and organic data have been treated separately. Health-based maximum contamination levels (MCLs) for inorganic substances and background concentrations are applied to identify inorganic contamination. Organic data in the form of TVPPs are considered after the inorganics.

Results of Inorganic Analysis

Arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver are the only elements for which MCLs have been established (Table 4-10). Of these, cadmium, chromium, lead, mercury, and selenium were detected at the site in concentrations exceeding their respective MCLs (Figure 4-28). Appendices A-1 and A-2 contain the complete listing of analytical data. Appendix A-3 summarizes inorganic concentrations with respect to MCLs. The following is a summary of inorganic contamination presented by element.

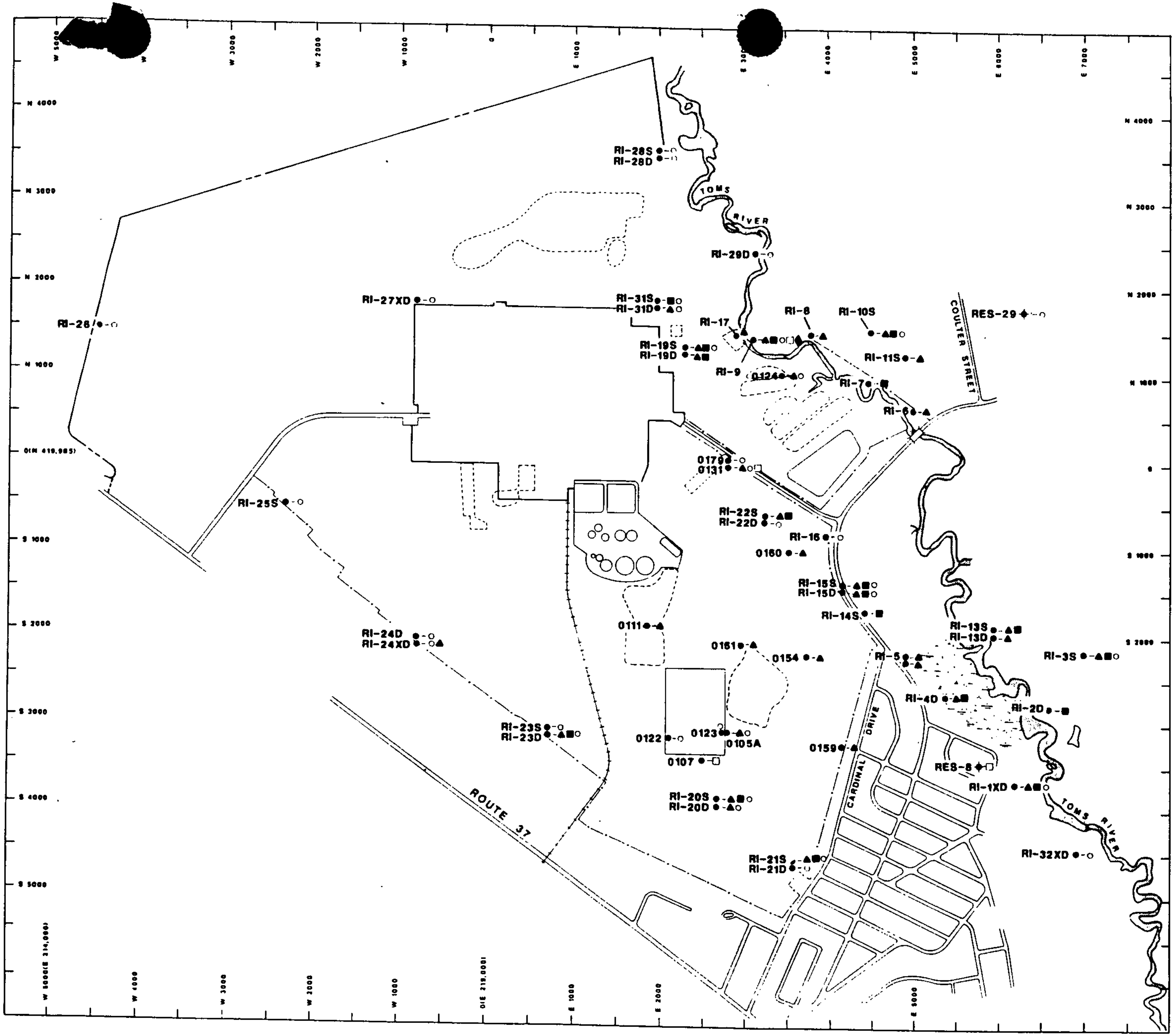
Arsenic

Sampling conducted by NUS/EPA detected arsenic on the Ciba-Geigy Site only at well 124. This arsenic concentration (14 ug/L) was below the MCL. Arsenic was detected in three offsite wells. All of these offsite arsenic detections (11-16 ug/L) were below the MCL. Groundwater sampling conducted by Ciba-Geigy prior to 1983 (Clement Associates, Inc., 1983) suggests that the Filtercake Disposal Area may be a source of arsenic groundwater contamination (Table 3-9). Additional sampling immediately downgradient of the Filtercake Disposal Area may be warranted.

TABLE 4-10
INORGANIC MAXIMUM CONTAMINATION LEVELS (MCLs)

Element	MCL (ug/L)
Arsenic	50
Barium	1000
Cadmium	10
Chromium	50
Lead	50
Mercury	2
Selenium	10
Silver	50

SOURCE: Code of Federal Regulations (40 CFR, Ch. 1, S141.13, July 1, 1986).



WELLS WITH INORGANIC CONTAMINANT CONCENTRATIONS ABOVE MAXIMUM CONTAMINATION LIMITS (MCL)

LEGEND

—+—+— RAILROAD SPUR
—·—·— SURVEYED BOUNDARY
—··—··— BOUNDARY FENCE
-------- BOUNDARY ROAD
▲ CADMIUM
■ CHROMIUM
□ MERCURY
○ LEAD
♦ SELENIUM
✦ RESIDENTIAL WELL
● MONITORING WELL

FIGURE 4-28

NUS CORPORATION

6.5 Other Sampling Results

Surface water and sediment samples for analyses of Priority Pollutants were collected from the marshland adjacent to the Toms River immediately northeast of the Oak Ridge Subdivision. Investigation of potential contamination resulting from the discharge of contaminated groundwater to this marshland was undertaken during March 1986 by JTC Environmental Consultants under the direction of the ENVIRON Corporation for Ciba-Geigy. Sampling results were subsequently incorporated into the ENVIRON Corp. Risk Assessment for groundwater contamination at the Ciba-Geigy Site. Appendix A-2 presents a summary of the analytical data.

Table 6-6 lists the contaminants found in sediment and aqueous samples collected from the marsh. The locations chosen by JTC Environmental Consultants for the collection of these samples are depicted in Figure 6-5.

Eight volatile organic contaminants were found upon analyses of the marshland sediments. Benzene was found at concentrations ranging from 2 to 207 ug/kg. Chlorobenzene was present at concentrations ranging from trace quantities to 445 ug/kg. Chloroform was present in trace quantities up to a concentration of 332 ug/kg. Tetrachloroethylene was found at concentrations ranging from 14 to 440 ug/kg. The concentrations of 1,1,2-trans-dichloroethylene were from 1 to 28 ug/kg. 1,1,1-Trichloroethane was present in concentrations ranging from 1 to 30 ug/kg. Concentrations of trichloroethylene from 1 to 525 ug/kg were detected. Finally, xylenes were present at concentrations ranging from 10 to 27 ug/kg.

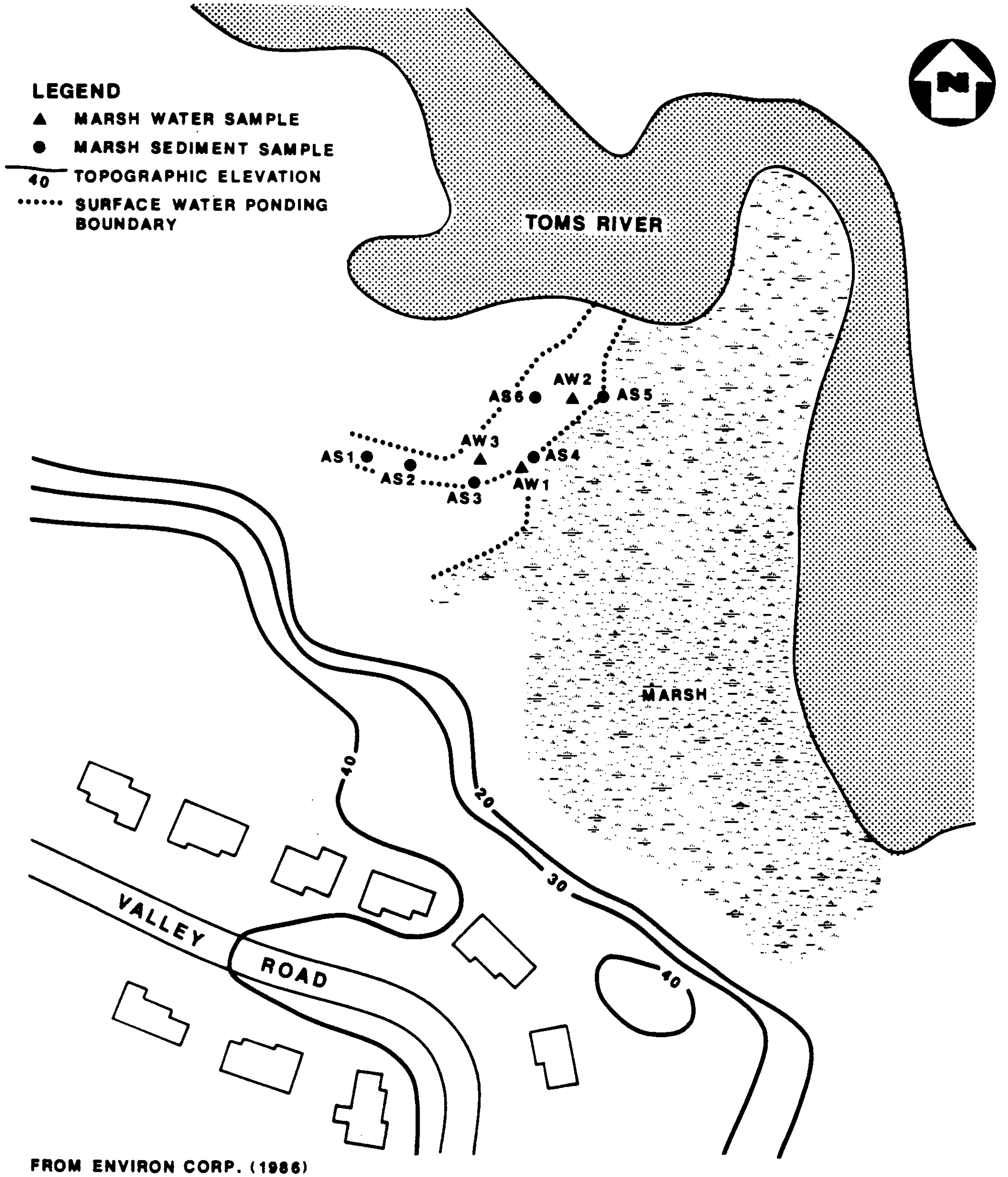
Three semivolatile organic contaminants were detected in the marshland sediments. Nitrobenzene was present in trace quantities. 1,2-Dichlorobenzene was found in amounts ranging from 200 to 560 ug/kg. Finally, 1,2,4-Trichlorobenzene was detected at concentrations ranging from 120 to 610 ug/kg.

TABLE 6-6
RESULTS OF MARSHLAND SEDIMENT AND SURFACE WATER SAMPLING
SAMPLES COLLECTED BY JTC ENVIRONMENTAL CONSULTANTS IN MARCH 1986

	Marshland Sediment (Concentration in ug/kg)						Marshland Water (Concentration in ug/L)		
Compound	AS1	AS2	AS3	AS4	AS5	AS6	AW1	AW2	AW3
Volatiles									
Benzene	BDL	56	207	8	2	25	18	22	29
Chlorobenzene	3*	304	445	163	5	363	39	44	75
Chloroform	2*	332	162	70	19	21	119	104	119
Tetrachloroethylene	14	406	440	337	65	217	52	51	58
1,2-trans-Dichloroethylene	4*	8	28	BDL	1*	23	6	24	17
1,1,1-Trichloroethane	BDL	BDL	1	30	BDL	BDL	BDL	BDL	BDL
Trichloroethylene	39	492	525	140	29	275	108	132	163
Xylenes	BDL	22	27	10	BDL	BDL	2*	2*	2*
Semivolatiles									
1,2-Dichlorobenzene	BDL	350	BDL	560	BDL	200	14	24	14
Naphthalene	BDL	BDL	BDL	BDL	BDL	BDL	1*	2*	2*
Nitrobenzene	BDL	100*	BDL	110*	BDL	BDL	8*	10	6*
1,2,4-Trichlorobenzene	BDL	310	160	370	120	610	4*	18	7*

BDL = Below Detection Limit

*Found below method detection limit.



FROM ENVIRON CORP. (1986)

LOCATIONS OF SAMPLES COLLECTED IN MARCH 1986
BY JTC ENVIRONMENTAL CONSULTANTS
CIBA-GEIGY SITE, DOVER TWP., N.J.

(NOT TO SCALE)

FIGURE 6-5

NUS CORPORATION

With regard to the water samples collected from these marshlands, six volatile and three semivolatile organic contaminants were detected at concentrations above the laboratory method detection limits. Ranges of volatile organic compounds detected were as follows: benzene (18-29 ug/L), chlorobenzene (39-75 ug/L), chloroform (104-119 ug/L), tetrachloroethylene (51-58 ug/L), 1,2-trans-dichloroethylene (6-24 ug/L), and trichloroethylene (108-163 ug/L). Ranges of semivolatile organic compounds found in the marshland waters were as follows: 1,2-dichlorobenzene (14-24 ug/L), nitrobenzene (trace quantities to 10 ug/L), and 1,2,4-trichlorobenzene (trace quantities to 18 ug/L).

6.6 Correlation with Other RI Sampling Results

Surface water contamination in the Toms River adjacent to the Ciba-Geigy cooling water intake may be correlated with groundwater contamination beneath the river. Soil samples collected from intermittent drainage courses crossing the Ciba-Geigy Site were found to be relatively free of HSL contaminants. Further, contaminants that are found in the soils of on-site intermittent drainage courses are not transported by runoff into the Toms River. Surface waters of the river were found to be free of those contaminants detected in on-site soils. Therefore, surface water contaminants appear to have been introduced via groundwater discharge to the river.

6.7 Conclusions

Analytical results of the surface water and sediment investigation indicate that contamination of the surface waters of the Toms River has occurred from past or present practices at Ciba-Geigy. The following HSL contaminants were found in the surface waters or sediments of the Toms River: (1) trichloroethene; (2) phenol; (3) chlorobenzene; and (4) benzene. Trichloroethene was found at concentratons up to 5.6 ug/L in the surface waters. Chlorobenzene was present in the sediments at trace quantities in the Toms River adjacent to the Ciba-Geigy cooling water intake. Both contaminants are attributed to the discharge of contaminated groundwater to the river. Phenol was detected in the cooling water discharge channel. Finally, benzene was present in the sediments at trace quantities in the Toms River downstream of the Ciba-Geigy Site.

7.0 BIOTA INVESTIGATION

The objective of the Biota Investigation was to establish a preliminary assessment of the impact of potential contaminant migration from the Ciba-Geigy Site upon the aquatic flora and fauna of the Toms River.

7.1 Biota Present

The Toms River basin is the northernmost of three large river systems confined to the Pine Barrens of New Jersey. As in other areas of the Pine Barrens ecosystem, floral and faunal species common to this drainage basin are greatly influenced by regional hydrogeology and hydrogeochemistry.

Terrestrial Biota

Vegetation within the Toms River basin is defined by two distinct floristic habitats: lowlands with saturated soils, and uplands with a water table greater than 0.7 meter below the soil surface. Lowland vegetation consists of broadleaf swamp forests of red maple, gum, and sweetbay found along riverine floodplains and freshwater marshes. Upland vegetation of the forest canopy is dominated by pitch pine, short leaf pine, blackjack oak, and black oak. Woody undergrowth is of a heath type, dominated by lowbush blueberry, black huckleberry, and greenbrier (Forman, 1979). Table 7-1 presents the species of flora common to the Toms River drainage basin in Ocean County, New Jersey.

The Toms River basin provides sufficient habitat to support a balanced faunal community. Whitetail deer frequent the upland forests. Other small mammals including raccoon, opossum, muskrat, gray and red squirrel, eastern cottontail rabbit, and gray fox are common to the drainage basin. Table 7-2 presents the species of fauna common to the Toms River drainage basin in Ocean County, New Jersey.

TABLE 7-1
FLORA COMMON TO THE TOMS RIVER DRAINAGE BASIN
OCEAN COUNTY, NEW JERSEY

TREE SPECIES

1. Birch, Gray
Betula populifolia

2. Cedar, Red
Juniperus virginiana

3. Cherry, Black
Prunus serotina

4. Cherry, Choke
Prunus virginiana

5. Gum, Sour
Nyssa sylvatica

6. Hickory, Mockernut
Carya tomentosa

7. Holly, American
Ilex opaca

8. Maple, Red
Acer rubrum

Oak, Black
Quercus velutina

10. Oak, Blackjack
Quercus marilandica

Oak, Chestnut
Quercus prinus

12. Oak, Post
Quercus stellata

13. Oak, Scarlet
Quercus coccinea

14. Oak, Scrub
Quercus ilicifolia

15. Oak, Southern Red
Quercus falcata

16. Oak, White
Quercus alba

Oak, Willow
Quercus phellos

18. Pine, Pitch
Pinus rigida

19. Pine, Short Leaf
Pinus echinata

20. Pine, Scrub
Pinus virginiana

21. Sassafras
Sassafras albidum

22. Sweetbay
Magnolia virginiana

SHRUB SPECIES

1. Alder, Common
Alnus serrulata

2. Arrowwood
Viburnum dentatum

3. Azalea, Swamp
Rhododendron viscosum

4. Bayberry, Common
Myrica pennsylvanica

5. Blackberry, Running Swamp
Rubus allegheniensis

6. Blueberry, Highbush
Vaccinium corymbosum

7. Chokeberry, Red
Pyrus arbutifolia

8. Chokeberry, Black
Pyrus melanocarpa

9. Cranberry, Native
Vaccinium macrocarpon

10. Dewberry
Rubus flagellaris

11. Elder, Marsh
Iva frutescens

12. Fetterbush
Leucothoe racemosa

13. Greenbrier, Common
Smilax rotundifolia

14. Groundsel, Bush
Baccharis halimifolia

15. Huckleberry, Black
Gaylussacia baccata

16. Hudsonia, Heathlike
Hudsonia tomentosa

17. Inkberry (Low Gallberry Holly)
Ilex glabra

18. Laurel-leaved smilax
Smilax laurifolia

19. Laurel, Mountain
Kalmia latifolia

20. Laurel, Sheep
Kalmia angustifolia

21. Leatherleaf
Chamaedaphne calyculata

22. Partridge Berry
Mitchella repens

23. Poison Ivy
Rhus radicans

24. Prickly Pear Cactus
Opuntia humifusa

25. Sand Myrtle
Leiophyllum buxifolium

26. Shadbush
Amelanchier spp.

27. Staggerbush
Lyonia mariana

28. Sumac, Staghorn
Rhus typhina

29. Sweet Pepperbush
Clethra alnifolia

30. Winterberry
Ilex verticillata

31. Wintergreen, Spotted
Chimaphila maculata

TABLE 7-1 (Cont'd)
FLORA COMMON TO THE TOMS RIVER DRAINAGE BASIN
OCEAN COUNTY, NEW JERSEY

HERBACEOUS PLANTS

1.	Aster, Heath	**Aster ericoides**
2.	Bulrush, Olney's	**Scirpus olneyi**
3.	Broom Sedge	**Andropogon virginicus**
4.	Cotton Grass, Tawny	**Eriophorum virginicum**
5.	Goldenrod, Seaside	**Solidago sempervirens**
6.	Grass, Black	**Juncus gerardi**
7.	Grass, Nut	**Cyperus esculentus**
8.	Grass, Spike	**Distichlis spp.**
9.	Horse-weed	**Erigeron canadensis**
0.	Indian-Pipe	**Monotropa uniflora**
1.	Joe-Pye-weed	**Eupatorium purpureum**
12.	Joint-Weed, Coast	**Polygonella polygama**
13.	Lady's Slipper, Pink	**Cypripedium acaule**
14.	Lobelia, Nuttall's	**Lobelia nuttallii**
15.	Mallow, Swamp Rose	**Hibiscus palustris**
16.	Mallow, Seashore	**Kosteletzkya virginica**
	Meadow Beauty	**Rhexia mariana**
8.	Mullein, Common	**Verbascum thapsus**
19.	Orache, Malberd-Leaved	**Atriplex patula**
20.	Phragmites	**Phragmites communis**
21.	Pink, Marsh	**Sabatia stellaris**
22.	Rose, Marsh	**Rosa palustris**
23.	Rush, Chairmaker's	**Scirpus americanus**
24.	Rush, Path	**Juncus tenius**
25.	Sandwort, Pine Barrens	**Arenaria caroliniana**
26.	Seedbox	**Ludwigia alternifolia**
27.	Sheep Sorrel	**Rumex acetosella**
28.	Sundew, Round-Leaved	**Drosera rotundifolia**
29.	Sundew, Thread-Leaved	**Drosera filiformis**
30.	Sunflower, Narrow-Leaved	**Helianthus angustifolius**
31.	Thistle, Field	**Cirsium discolor**
32.	Thoroughwort, Round-Leaved	**Eupatorium rotundifolium**
33.	Thoroughwort, Hairy	**Eupatorium pilosum**
34.	Tickseed-Sunflower	**Bidens aristosa**
35.	Tick-Trefoil, Hoary	**Desmodium canescens**
36.	Toadflax, Blue	**Linaria canadensis**
37.	Turkeybeard	**Xerophyllum asphodeloides**
38.	Venus' Looking-Glass	**Specularia perfoliata**
39.	Whitlow-Grass	**Draba verna**

LOWER PLANTS

1.	Club-Moss, Bog	**Lycopodium inundatatum**
2.	Ground Pine	**Lycopodium obscurum**
3.	Fern, Bracken	**Pteridium aquilinum**
4.	Fern, Hay-Scented	**Dennstaedtia punctilobula**
5.	Fern, Cinnamon	**Osmunda cinnamomea**
6.	Fern, Marsh	**Dryopteris thelypteris**
7.	Fern, Netted Chain	**Woodwardia areolata**
8.	Fern, Royal	**Osmunda regalis**
9.	Lichen, British Soldier	**Cladonia cristatella**
10.	Moss, Haircap	**Polytrichum juniperinum**
11.	Moss, Sphagnum	**Sphagnum palustre**

TABLE 7-2
FAUNA COMMON TO THE TOMS RIVER DRAINAGE BASIN
OCEAN COUNTY, NEW JERSEY

MAMMALS

1. Deer Mouse
   Peromyscus maniculatus

2. Eastern Cottontail Rabbit
   Sylvilagus floridanus

3. Gray Fox
   Urocyon cinereoargenteus

4. Gray Squirrel
   Sciurus carolinensis

5. Little Brown Bat
   Pipistrellus subflavus

6. Meadow Mole
   Scalopus aquaticus

Muskrat
Ondatra zibethicus

8. Opossum
   Didelphis marsupialis

9. Raccoon
   Procyon lotor

10. Red Squirrel
    Tamiasciurus hudsonicus

11. Whitetail Deer
    Odocoileus virginianus

AMPHIBIANS

1. Bullfrog
   Rana catesbeiana

2. Fowler's Toad
   Bufo woodhousei fowleri

3. Green Frog
   Rana clamitans melanota

4. Northern Leopard Frog
   Rana pipiens

5. Northern Dusky Salamander
   Desmognathus fuscus

6. Spring Peeper
   Hyla crucifer

7. Wood Frog
   Rana sylvatica

REPTILES

1. Black Racer Snake
   Coluber constrictor

2. Brown Snake
   Storeria dekayi

3. Common Garter Snake
   Thamnophis sirtalis

4. Common Snapping Turtle
   Chelydra serpentina

5. Eastern Box Turtle
   Terrapene carolina

6. Eastern Painted Turtle
   Chrysemys picta

7. Hognose Snake
   Heterodon platyrhinos

8. King Snake
   Lampropeltis getulus

9. Northern Water Snake
   Natrix sipedon

10. Pine Snake
    Pituophis melanoleucus

11. Rough Green Snake
    Opheodrys aestivus

12. Spotted Turtle
    Clemmys guttata

13. Worm Snake
    Carphophis amoenus

FISHES

1. American Eel
   Anguilla rostrata

2. Banded Sunfish
   Enneacanthus obesus

3. Brown Bullhead
   Ictalurus nebulosus

4. Chain Pickerel
   Esox niger

5. Chub Sucker
   Erimyzon oblongus

6. Johnny Darter
   Etheostoma olmstedi

7. Mud Sunfish
   Acantharchus pomotis

8. Pirate Perch
   Aphredoderus sayanus

9. Sphagnum Sunfish
   Enneacanthus chaetodon

10. Yellow Bullhead
    Ictalurus natalis

Aquatic Biota

Waters of the Toms River are of sufficient quality to support a diversity of aquatic species adapted to naturally acidic environments. As in other acidic Pine Barrens river systems, the waters of the Toms River are high in dissolved oxygen but low in alkaline metal content.

Aquatic Fauna

The Toms River presently supports a variety of acid-water species including the chub sucker, chain pickerel, banded sunfish, mud sunfish, yellow bullhead, brown bullhead, and pirate perch. Amphibians and reptiles are well represented throughout the drainage basin (Forman, 1979). Table 7-2 presents a list of the fish, amphibian, and reptilian species common to the Toms River drainage basin.

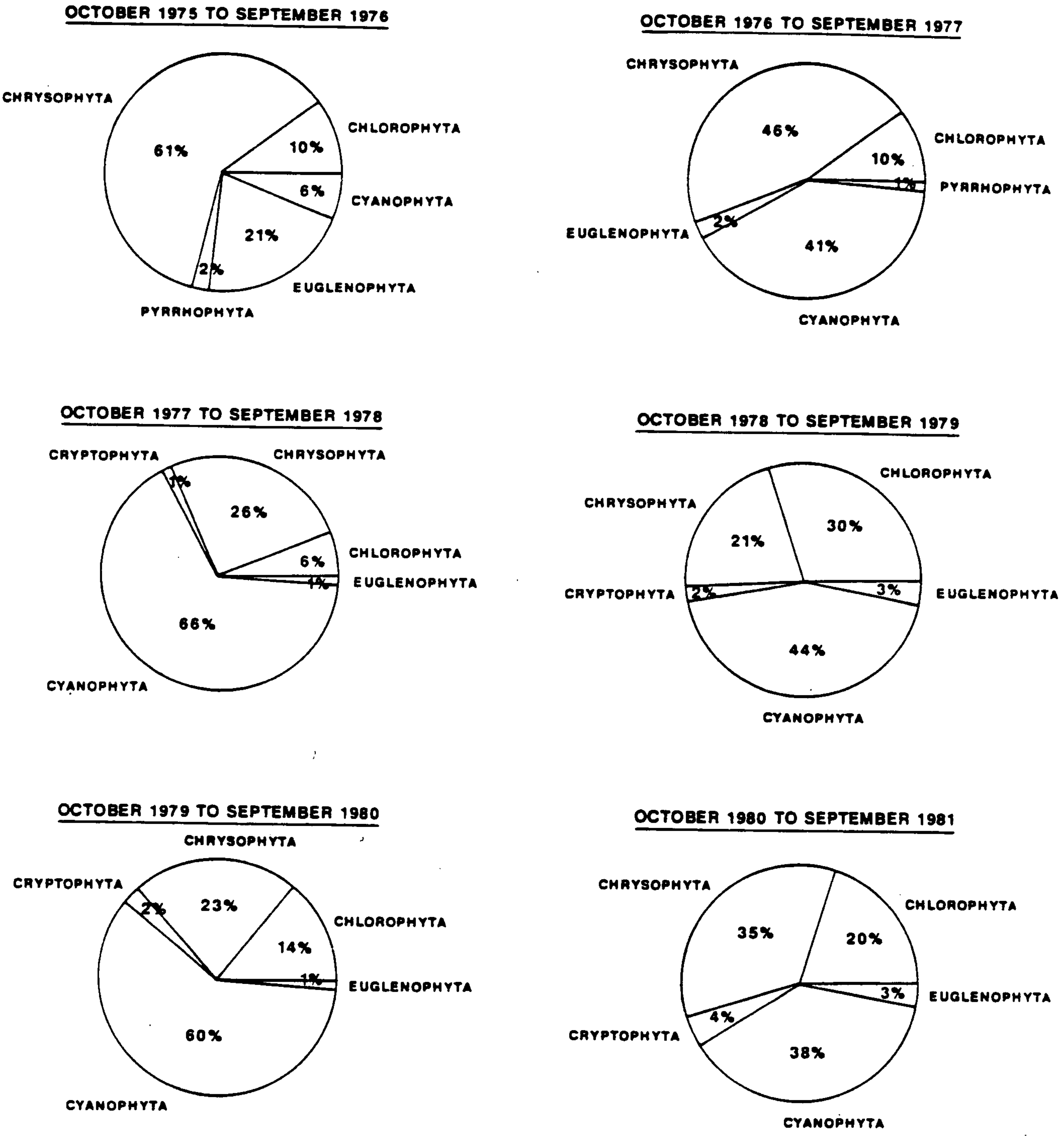
The historical impact of the Toms River Chemical Company upon the aquatic fauna of the Toms River was first documented by the New Jersey Division of Fish and Game in a 1964 report summarizing 2 years of sampling efforts. During this time period, the Toms River Chemical Company was discharging treated effluents directly to the Toms River. In 1962, three 750-foot segments of the Toms River were sampled using Rotenone and "fine net" block seines. A total of 2.4 pounds of fish were collected at the control station, of which four individuals were of sufficient size for dissection. In the two sampling areas considered to be affected by Toms River Chemical, six fish were collected, only one of which was of sufficient size for dissection. The maximum estimated yield of fish in the impacted segment of the river was 0.3 lbs/acre. The major finding of this study was that the riverine areas adjacent to the Toms River Chemical Site and immediately downstream "were both practically devoid of fish life". However, bioassay studies indicated that, in general, the effluent discharged from the site to the Toms River seldom reached concentrations directly toxic to fish. Based on stomach content analyses, the absence of fish in these reaches of the Toms River was instead attributed to the absence of their primary food source, aquatic insects.

Aquatic Flora

Phytoplankton species diversity in the Toms River has been well documented by the U.S. Geological Survey (U.S.G.S). The U.S.G.S. maintains a gage station (No. 01408500) at the Oak Ridge Parkway Bridge, downstream of the Ciba-Geigy cooling water intake and discharge points. From 1975 through 1981, the U.S.G.S. conducted a survey of the water quality and phytoplankton populations of the Toms River (U.S.G.S. Water-Data: NJ-76-1 to NJ-81-1). This water quality survey included seston sampling (sampling of phytoplankton plus suspended inorganic and organic matter) for the analyses of As, Cr, Cu, Fe, Pb, and Hg, and periphyton sampling (sampling of algal growth on the streambed) for the determination of the benthic algal biomass.

The historical impact of the Ciba-Geigy Site upon the water quality of the Toms River may be reflected by the changes in phytoplankton species composition. In September 1977, Ciba-Geigy completed a modernization program for their wastewater treatment facilities. Activated sludge and secondary clarification units replaced the unlined oxidation, settling, and aeration lagoons located adjacent to the river. After the new wastewater treatment plant was operational, these lagoons were drained and backfilled to grade with soil. Presently, Ciba-Geigy obtains noncontact cooling water from the Toms River at a flow rate of 11 MGD. Two million gallons of this are used for general housekeeping and boiler feed, then treated and released with process water to the ocean outfall (CAI, 1983). The remainder of the noncontact cooling water is returned to the river. Changes in the Ciba-Geigy physical plant in conjunction with modernization of the wastewater treatment facilities in 1977 may be responsible for changes in the species composition of phytoplankton populations found in the Toms River.

Figure 7-1 depicts the phytoplankton species composition in the Toms River from October 1975 through September 1981. Prior to September 1977, phytoplankton species representing five divisions - Chrysophyta (diatoms), Euglenophyta (Euglena), Cyanophyta (blue-green algae), Chlorophyta (green algae), and Pyrrhophyta (fire algae) - were prevalent in the river. The Chrysophyta dominated the phytoplankton populations, with the Euglenophyta and the Cyanophyta represented as important species.



* COMPILED FROM THE USGS WATER RESOURCES DATA NEW JERSEY WATER YEARS 1976 TO 1981

FIGURE 7-1

DOMINANT PHYTOPLANKTON POPULATIONS FOUND IN THE TOMS RIVER, TOMS RIVER, NEW JERSEY

NUS CORPORATION

After 1977, a marked shift in algal species from members of the Chrysophyta to species from the Cyanophyta occurred. The Chrysophyta decreased in abundance while species from the Chlorophyta increased in abundance. Euglenoid algae, common to ammonia-rich waters, were important species in 1975; however, after 1977 the Euglenophyta were a minor constituent of the phytoplankton of the river (Wetzel, 1975). The Pyrrhophyta were not represented in phytoplankton populations after 1977, while species from the Cryptophyta were introduced to the river.

The shift in algal species dominance after 1977 may be correlated with changes in the aquatic chemistry of the Toms River. Table 7-3 summarizes the macronutrient concentrations, metal concentrations present in the seston, and periphyton biomass found in the Toms River from 1975 to 1981 at U.S.G.S gage station 01408500. Dissolved oxygen and pH were stable during the period. Total nitrogen and total phosphorus were at sufficient concentrations to support eutrophic conditions in the river. Seston samples (phytoplankton plus suspended inorganic and organic matter) showed elevated levels of chromium, copper, and lead prior to 1977. Dissolved metals usually suppress algal growth; however, no indication of a decrease in periphyton biomass is evident prior to 1977. From 1975 to 1981 total nitrogen showed a general trend toward decreasing concentration. Periphyton biomass decreased significantly during this period from a maximum yield of 65.7 g/m^2 in 1975 to a maximum yield of 7.6 g/m^2 in 1981. The decrease in available nitrogen, together with the corresponding significant decrease in periphyton biomass, is indicative of the decreased potential for the surface waters of the Toms River to support algal growth. This decreased potential for the surface waters to support algal growth may be attributed to the improving water quality of the Toms River.

TABLE 7-3
THE RANGE OF BASELINE CHEMICAL PARAMETERS, METAL CONCENTRATIONS PRESENT IN THE SESTON AND THE PERIPHYTON BIOMASS FOUND IN THE TOMS RIVER AT U.S.G.S GAGE STATION 01408500 FOR NEW JERSEY WATER YEARS 1976 TO 1981*

	BASELINE CHEMICAL PARAMETERS			
New Jersey Water Year	pH	Dissolved Oxygen mg/L	Total Nitrogen mg/L	Total Phosphorus mg/L
10/80 to 9/81	4.1-6.2	8.0-12.4	0.36-1.10	0.01-0.06
10/79 to 9/80	4.1-6.1	7.9-12.4	0.51-1.00	0.03-0.09
10/78 to 9/79	4.0-6.1	7.9-13.0	0.51-0.91	0.02-0.08
10/77 to 9/78	4.0-4.9	7.2-13.8	0.53-1.10	0.01-0.07
10/76 to 9/77	4.4-6.2	7.3-15.0	0.70-1.40	0.02-0.09
0/75 to 9/76	4.1-6.4	8.1-13.0	0.48-1.80	0.03-0.09

	METAL CONCENTRATIONS ug/L PRESENT IN THE SESTON						PERIPHYTON BIOMASS DRY WEIGHT g/m^2
New Jersey Water Year	As	Cr	Cu	Fe	Pb	Hg	
10/80 to 9/81	0-1	0-10	0-10	140-1200	1-12	0	---
10/79 to 9/80	0-3	0-10	0-1	200-1600	1-17	0	0.08-7.64
10/78 to 9/79	0-1	0-10	0-2	110-1300	0-5	0	1.81-28.5
10/77 to 9/78	0-1	9-10	0-9	1100-1800	0-22	0	---
10/76 to 9/77	0	9-23	1-11	---------	3-49	0-0.2	1.50-11.0
10/75 to 9/76	0-1	0	0	---------	0-5	0	3.70-65.7

*U.S.G.S. Water Data: NJ-76-1 to NJ-81-1

------- Missing Data

7.2 Technical Approach

Field investigations were initiated to assess the environmental impact of the Ciba-Geigy Site upon the aquatic biota of the Toms River, and to assess the potential for human exposure to contaminants through the ingestion of contaminated shellfish. Field studies of the biota program were conducted according to the proposed scope of work with one exception. Sampling of the freshwater fishes of the Toms River, with subsequent analysis of fish tissues for the determination of HSL contaminant bioaccumulation, was not conducted. Fish surveys of the Toms River show that the American eel, Johnny darter, pirate perch, and banded sunfish are common to the river. However, larger native fish species, such as yellow bullhead and brown bullhead catfish, and chain pickerel are not frequently encountered. Consequently, sufficient biomass of fish tissues would not be obtained without the collection of a prohibitively large number of small fishes. Further, introduction of a nonnative fish species for bioaccumulation studies would have proven to be unfeasible due to the low pH of the surface waters.

Algal studies of Hazardous Substance List (HSL) contaminant uptake by the periphyton were initiated upstream from, adjacent to, and downstream from the Ciba-Geigy Site. After 45 days, periphyton growth had not accumulated sufficient biomass for sample collection and laboratory analysis. As a result, the periphyton sampling program was abandoned. Aquatic insect studies were then initiated as an alternative to the periphyton program, with aquatic insect populations surveyed to determine the impact of the Ciba-Geigy Site upon species richness and diversity in the Toms River.

Five sampling locations (Figure 7-2) were designated for placement of periphyton sampling plates and for the survey of aquatic insect populations:

- Location 1: Toms River at Riverwood Park, upstream from the Ciba-Geigy Site.
- Location 2: Toms River at the Rte. 571 Bridge, upstream from Ciba-Geigy.
- Location 3: Toms River at the Oakridge Parkway Bridge, at and immediately below the confluence with the Ciba-Geigy cooling water channel.
- Location 4: Toms River adjacent to Cadillac Drive, downstream from the Ciba-Geigy Site.
- Location 5: Toms River at the Rte. 37 Bridge, downstream from Ciba-Geigy.

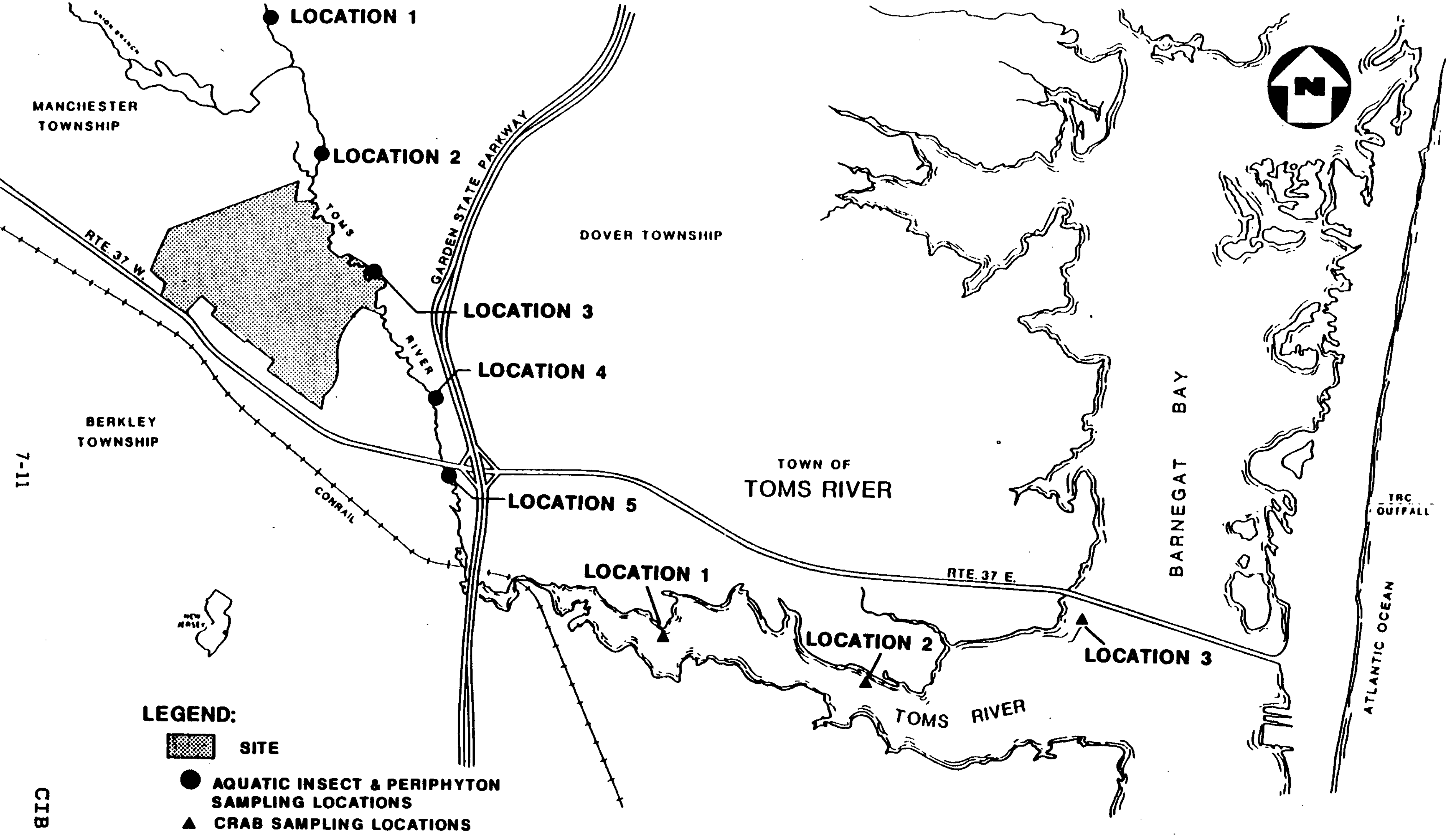


FIGURE 7-2

NUS CORPORATION

BIOTA SAMPLING LOCATIONS
CIBA-GEIGY SITE, DOVER TWP., N.J.

Selection of sampling locations was based primarily on limiting the variability in habitat, flow characteristics, sediment type, and other physical parameters between stations. Minimizing interstation variability was required to provide comparability of biological data sufficient to meet the objective of the study, to screen for water-quality-related impacts on the biota. Where possible, stations were located to maintain comparability with prior studies (N.J. Division of Fish and Game, 1964). The aquatic insect sampling and distribution of periphyton samplers covered river segments 200 to 300 feet in length. Microhabitats within the segments were individually sampled. Consequently, it was not possible to determine the precise locations of sample recovery within the stream channel at each sampling location.

Sampling of blue crabs using standard bailed traps was also conducted as part of the biota investigation. Three sampling locations (Figure 7-3) were designated for the collection of blue crabs from the estuarine reaches of the Toms River:

- Location 1: Toms River, in the upper reaches of the estuary along the left bank (northern shoreline).
- Location 2: Toms River, in the mid-reaches of the estuary along the left bank.
- Location 3: Toms River, at the confluence of the Toms River estuary and Barnegat Bay along the north point of the inlet.

7.3 Biota Sampling Results

Analytical results of biota sampling in the Toms River are presented in the following subsections.

7.3.1 Periphyton Sampling

Periphyton sampling in the Toms River was undertaken to determine uptake and bioaccumulation of HSL contaminants allegedly emanating from the Ciba-Geigy Site. NUS Corporation Region 2 FIT placed periphyton sampling plates both upstream and downstream of the Ciba-Geigy Site at the locations depicted in Figure 7-2. Sampling racks were placed in the river at middepth on May 6, 1985. Periphyton growth on the sampling plates was then monitored on a biweekly basis until the end of June. After 45 days, periphyton growth had not accumulated sufficient biomass for sample collection and laboratory analysis. As a result, the periphyton sampling program was concluded.

Poor growth performance on the periphyton sampling plates may be attributed to high stream flows. Increased stream discharge during storm events may have scoured periphyton growth from the sampling plates. High stream flows were recorded on June 2, 18, and 26, with stream discharges of 160, 189, and 179 cf/s for the respective events, as recorded at the U.S.G.S. gage station at Oak Ridge Parkway (U.S.G.S. Water-Data: NJ-85-1).

Poor growth performance on the periphyton sampling plates also may be correlated with the improved water quality of the Toms River. The potential for the waters of the Toms River to support periphyton growth may have decreased due to changes in the aquatic chemistry, as evidenced in Table 7-3. From 1975 to 1981, the average total nitrogen concentration in the surface waters decreased by 36 percent. Periphyton biomass decreased significantly during this period from a maximum yield of 65.7 g/m^2 in 1975 to a maximum yield of 7.6 g/m^2 in 1981. Further, phytoplankton studies conducted by the U.S.G.S. (U.S.G.S. Water-Data NJ-76-1 to NJ-81-1) show that, during this time span, the biomass to chlorophyll ratio was 5600:15600, indicative that the periphyton biomass was predominantly non-algal.

7.3.2 Aquatic Insect Sampling

An aquatic insect survey of the Toms River was conducted on July 23 and 24, 1985, by NUS Corporation Region 2 FIT to assess the environmental impact of the Ciba-Geigy Site upon downstream aquatic insect populations. Five locations, presented in Figure 7-2, were designated to sample insect populations, with two sampling stations situated upstream from the Ciba-Geigy Site and three sampling points located downstream from the site. Aquatic insects were collected using surber samplers and dipnets. Each surber sampler covered 1 ft^2 of substrate, with a 3-inch base extension to ensure capture of organisms within the substrate surface. Surber sampler capture nets were standard 1024-micron-mesh silk. A dipnet with 800- by 200-micron multifilament nylon netting was used to collect insects associated with submerged leaf litter and vegetation.

Population surveys of the aquatic insects found in the Toms River were used to model the biological response to alleged contaminant release from the Ciba-Geigy Site. Species dominance was calculated using the Simpson Index of Dominance (Simpson, 1949). Overall species distribution was determined by calculation of the Evenness Index as defined by Pielou (1966). Finally, potential changes in species diversity in response to adverse environmental conditions associated with the the Ciba-Geigy Site were calculated using the Shannon Index of General Diversity (Shannon and Weaver, 1963).

Figure 7-3 depicts the species composition of the aquatic insects found in the Toms River surber samples. These aquatic insects were enumerated by taxonomic order and family for comparison. Eight orders of aquatic insects - Megaloptera (hellgrammites), Odonata (dragonflies and damselflies), Plecoptera (stoneflies), Coleoptera (aquatic beetles), Hemiptera (aquatic bugs), Ephemeroptera (mayflies), Trichoptera (caddisflies), and Diptera (craneflies, blackflies, mosquitoes, and other flies) - were represented by 16 families of 17 genera.

Table 7-4 summarizes the aquatic insect populations found in the Toms River surber samples. Trichoptera was the dominant order within insect populations surveyed at four out of five locations in the Toms River. Upstream of the Ciba-Geigy Site, the Trichoptera comprised 80 and 84 percent of the aquatic insects present in samples collected at Stations 1 and 2, respectively. Trichopteran species of the family Brachycentridae were the dominants at both Stations 1 and 2. No aquatic insects were found at Station 3 located immediately downstream of the Ciba-Geigy cooling water discharge channel. Downstream from the Ciba-Geigy Site, the Trichoptera comprised 54 and 74 percent of the aquatic insects present in samples collected from Stations 4 and 5, respectively. At Station 4 however, the dominant species were of the family Tipulidae, order Diptera. Trichopteran species of the family Leptoceridae were the dominant aquatic insects in samples collected at Station 5.

Based on the above sampling results, the Ciba-Geigy Site appears to directly directly impacts aquatic insect populations of the Toms River adjacent to and immediately downstream from the cooling water discharge channel. However, changes in the species contribution to downstream populations of aquatic insects found in the Toms River surber samples cannot be attributed to contamination

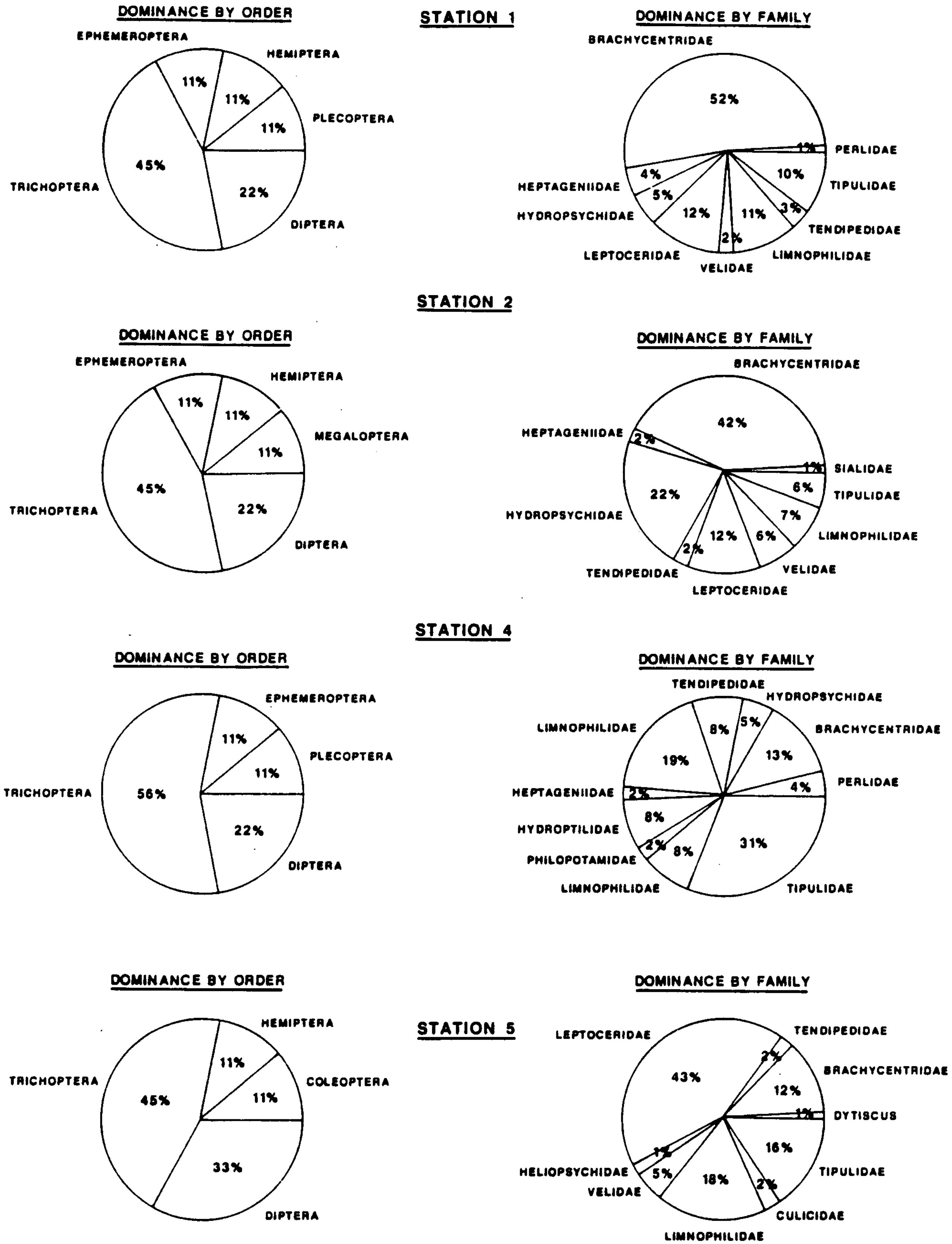


FIGURE 7-3

NUS CORPORATION

DOMINANT AQUATIC INSECT POPULATIONS FOUND IN THE TOMS RIVER, TOMS RIVER, NEW JERSEY SURBER SAMPLES COLLECTED JULY 23-24, 1985

TABLE 7-4
AQUATIC INSECT POPULATIONS FOUND IN THE TOMS RIVER, TOMS RIVER, NEW JERSEY
SURBER SAMPLES COLLECTED JULY 23-24, 1985

ORDER	FAMILY	GENERA	NUMBER OF INDIVIDUALS PER STATION*				
			1	2	3	4	5
					N		
Megaloptera	Sialidae	*Sialis*			O	1	
Odonata	Aeschnadae	*Aeschna*					
Plecoptera	Perlidae	*Acroneuria*	1		O	3	
Coleoptera	Dytiscidae	*Dytiscus*			R		1
Hemiptera	Velidae	*Microvelia*	3	15	G		6
Ephemeroptera	Heptageniidae	*Stenonema*	6	5	A	2	
Trichoptera	Hydropsychidae	*Hydropsyche*	8	25	N	4	
		Cheumatopsyche		31	I		
	Hydroptilidae	*Hydroptila*			S	6	
	Brachycentridae	*Brachycentrus*	80	106	M	10	13
	Leptoceridae	*Leptocella*	18	32	S	15	46
	Limnophilidae	*Hesperophylax*	17	18		6	20
	Heliopsychidae	*Heliopsyche*			F		1
	Philopotamidae	*Chimarra*			O	2	
Diptera	Tendipedidae	*Tendipedes*	4	4	U	6	2
	Culicidae	*Culex*			N		2
	Tipulidae	*Tipula*	16	15	D	25	17
			—	—	—	—	—
		TOTAL	153	252	0	79	108

Note* Location of Stations:

1 = Riverwood Park: Upstream from the Ciba-Geigy Site
2 = Rte. 571 Bridge: Upstream from the Ciba-Geigy Site
3 = Oakridge Parkway Bridge: Immediately downstream from the Ciba-Geigy cooling water discharge
4 = Cadillac Drive: Downstream from the Ciba-Geigy Site
5 = Rte. 37 Bridge: Downstream from the Ciba-Geigy Site

TABLE 7-4 (CONT'D)
RELATIVE FREQUENCY OF AQUATIC INSECT POPULATIONS FOUND IN THE TOMS RIVER, TOMS RIVER, NEW JERSEY
SURBER SAMPLES COLLECTED JULY 23-24, 1985

ORDER	FAMILY	GENERA	FREQUENCY(%) OF INDIVIDUALS PER STATION*				
			1	2	3	4	5
					N		
Megaloptera	Sialidae	Sialis		0.4	O		
Odonata	Aeschnadae	Aeschna					
Plecoptera	Perlidae	Acroneuria	0.7		O	3.8	
Coleoptera	Dytiscidae	Dytiscus			R		0.9
Hemiptera	Velidae	Microvelia	2.0	5.9	G		6
Ephemeroptera	Heptageniidae	Stenonema	3.8	2.4	A	2.5	
Trichoptera	Hydropsychidae	Hydropsyche	5.2	22.1	N	5.1	
		Cheumatopsyche			I		
	Hydroptilidae	Hydroptila			S	7.6	
	Brachycentridae	Brachycentrus	52.3	41.9	M	12.7	12.0
	Leptoceridae	Leptocella	11.8	12.6	S	19.0	42.6
	Limnophilidae	Hesperophylax	11.1	7.1		7.6	18.5
	Heliopsychidae	Heliopsyche			F		0.9
	Philopotamidae	Chimarra			O	2.5	
Diptera	Tendipedidae	Tendipedes	2.6	1.6	U	7.6	1.9
	Culicidae	Culex			N		1.9
	Tipulidae	Tipula	10.5	5.9	D	31.6	15.7

Note* Location of Stations:
1 = Riverwood Park: Upstream from the Ciba-Geigy Site
2 = Rte. 571 Bridge: Upstream from the Ciba-Geigy Site
3 = Oakridge Parkway Bridge: Immediately downstream from the Ciba-Geigy cooling water discharge
4 = Cadillac Drive: Downstream from the Ciba-Geigy Site
5 = Rte. 37 Bridge: Downstream from the Ciba-Geigy Site

from the Ciba-Geigy Site. The insect orders Trichoptera, Ephemeroptera, and Plecoptera are intolerant to pollution (Pennak, 1978). However, the Trichoptera dominated all insect populations surveyed in the river, both upstream and downstream from the site. Ephemeroptera of the family Heptageniidae were found upstream from the site at Stations 1 and 2, and were found downstream from the site at Station 4. Plecopteran species of the family Perlidae were found upstream from Ciba-Geigy at Station 1 and downstream from Ciba-Geigy at Station 4.

Table 7-5 summarizes the diversity indices calculated for the aquatic insect populations surveyed in the Toms River. Calculation of the Shannon Index of General Diversity, based on the identification and enumeration of surber samples, indicates that species diversity is not affected by discharges of Ciba-Geigy cooling water or by the alleged contamination from the Ciba-Geigy Site. Species diversity is similar at Stations 1 and 2, and similar at Stations 4 and 5, with a natural increase in species diversity occurring from the upstream to downstream waters of the Toms River. Calculation of the Evenness Index for aquatic insect populations found in surber samples from the river indicates a high probability of encounter for individuals of the same species; that is, the dominant species are evenly distributed throughout the aquatic habitat at each station.

Table 7-6 summarizes the aquatic insect populations found in the Toms River dipnet samples. Eight orders of aquatic insects (Megaloptera, Odonata, Plecoptera, Coleoptera, Hemiptera, Ephemeroptera, Trichoptera, and Diptera) were represented by 20 families of 22 genera (Figure 7-4). Upstream of the site at Stations 1 and 2, the dominant species were of the family Brachycentridae, order Trichoptera. Immediately at and below the confluence of the Toms River and the Ciba-Geigy cooling water discharge channel (Station 3), no species of aquatic insects were found in repeated dipnet samples. Below the Ciba-Geigy Site at Station 4, six insect orders (Megaloptera, Odonata, Hemiptera, Ephemeroptera, Trichoptera, and Diptera) were each represented by a single family. The dominant family at this location was Brachycentridae, order Trichoptera. Coleoptera and Trichoptera were the co-dominant insect orders at Station 5. The dominant species at this location were of the order Hemiptera, family Velidae.

TABLE 7-5
INDICES OF SPECIES DIVERSITY CALCULATED FOR THE AQUATIC INSECT POPULATIONS FOUND IN THE TOMS RIVER, NEW JERSEY

SAMPLES COLLECTED JULY 23-24, 1985

SHANNON INDEX OF GENERAL DIVERSITY CALCULATED FOR AQUATIC INSECT POPULATONS FOUND IN SURBER SAMPLES FROM THE TOMS RIVER.

$H = -\sum P_i \log_e P_i$ where:
Pi = importance probability for each species.

STATION:	1	2	3	4	5
H:	1.56	1.66		1.99	2.11
S.D = 0.19					

EVENNESS INDEX CALCULATED FOR AQUATIC INSECT POPULATIONS FOUND IN SURBER SAMPLES FROM THE TOMS RIVER.

$J = \frac{H}{\log_e S}$ where

H = Shannon Index
S = Number of Species

STATION:	1	2	3	4	5
J:	0.71	0.72		0.87	0.96

INDEX OF SIMILARITY CALCULATED FOR AQUATIC INSECT SAMPLES FOUND IN SURBER SAMPLES FROM THE TOMS RIVER

STATION:	1+2	1+4	1+5	2+4	2+5	4+5
S:	0.84	0.84	0.63	0.70	0.63	0.53

$S = \frac{2C}{A+B}$ where:

A = number of species in Sample A
B = number of species in Sample B
C = number of species common to both samples

SHANNON INDEX OF GENERAL DIVERSITY CALCULATED FOR AQUATIC INSECT POPULATONS FOUND IN DIPNET SAMPLES FROM THE TOMS RIVER.

$H = -\sum P_i \log_e P_i$ where:
Pi = importance probability for each species.

STATION:	1	2	3	4	5
H:	1.76	1.33	-	1.88	1.10
S.D = 0.12					

EVENNESS INDEX CALCULATED FOR AQUATIC INSECT POPULATIONS FOUND IN DIPNET SAMPLES FROM THE TOMS RIVER.

$J = \frac{H}{\log_e S}$ where

H = Shannon Index
S = Number of Species

STATION:	1	2	3	4	5
J:	0.80	0.47		1.05	0.48

TABLE 7-6
AQUATIC INSECT POPULATIONS FOUND IN THE TOMS RIVER, TOMS RIVER, NEW JERSEY
DIPNET SAMPLES COLLECTED JULY 23-24, 1985

ORDER	FAMILY	GENERA	NUMBER OF INDIVIDUALS PER STATION*				
			1	2	3	4	5
Megaloptera	Sialidae	*Sialis*				3	
Odonata	Aeschnadae	*Aeschna*		1		1	
	Cordulegastridae	*Cordulegaster*			N		1
Plecoptera	Perlidae	*Acroneuria*		4	O		
Coleoptera	Dytiscidae	*Dytiscus*					3
	Gyrinidae	*Gyrininae*			O		1
	Hydrophilidae	*Hydrophilus*	1		R		5
Hemiptera	Velidae	*Microvelia*	7	6	G	14	82
	Notonectidae	*Notonecta*	2	2	A		
	Gerridae	*Gerris*	1	1	N		
Ephemeroptera	Heptageniidae	*Stenonema*	24	10	I	17	1
choptera	Hydropsychidae	*Hydropsyche*	8	8	S		
		Cheumatopsyche		7	M		
	Hydroptilidae	*Hydroptila*			S		4
	Limnophilidae	*Hesperopylax*		1			
		Astenophylax			F		
	Brachycentridae	*Brachycentrus*	29	66	O	39	11
	Leptoceridae	*Leptocella*		1	U		
	Philopotamidae	*Chimarra*			N		1
Diptera	Culicidae	*Culex*	20		D	10	
	Tendipedidae	*Tendipedes*	6				4
	Tipulidae	*Tipula*		1			
		TOTAL	98	108	0	84	113

Note* Location of Stations:

1 = Riverwood Park: Upstream from the Ciba-Geigy Site
2 = Rte. 571 Bridge: Upstream from the Ciba-Geigy Site
3 = Oakridge Parkway Bridge: Immediately downstream from the Ciba-Geigy cooling water discharge
4 = Cadillac Drive: Downstream from the Ciba-Geigy Site
5 = Rte. 37 Bridge: Downstream from the Ciba-Geigy Site

TABLE 7-6 (CONT'D)
AQUATIC INSECT POPULATIONS FOUND IN THE TOMS RIVER, TOMS RIVER, NEW JERSEY
DIPNET SAMPLES COLLECTED JULY 23-24, 1985

ORDER	FAMILY	GENERA	FREQUENCY(%) OF INDIVIDUALS PER STATION*				
			1	2	3	4	5
Megaloptera	Sialidae	Sialis			NO ORGANISMS FOUND	3.6	
Odonata	Aeschnadae	Aeschna		0.9		1.2	
	Cordulegastridae	Cordulegaster					0.9
Plecoptera	Perlidae	Acroneuria		3.7			
Coleoptera	Dytiscidae	Dytiscus					2.7
	Gyrinidae	Cyrininae					0.9
	Hydrophilida	Hydrophilus	1.0				4.4
Hemiptera	Velidae	Microvelia	7.1	5.6		16.7	72.6
	Notonectidae	Notonecta	2.0	1.9			
	Gerridae	Gerris	1.0	0.9			
Ephemeroptera	Heptageniidae	Stenonema	24.5	9.3		20.2	0.9
Trichoptera	Hydropsychidae	Hydropsyche	8.2	7.4			
		Cheumatopsyche		6.5			
	Hydroptilidae	Hydroptila					3.5
	Limnophilidae	Hesperophylax		0.9			
		Astenophylax					
	Brachycentridae	Brachycentrus	29.6	61.1		46.4	9.7
	Leptoceridae	Leptocella		0.9			
	Philopotamidae	Chimarra					0.9
Diptera	Culicidae	Culex	20.4			11.9	
	Tendipedidae	Tendipedes	6.1				3.5
	Tipulidae	Tipula		0.9			

Note* Location of Stations:

1 = Riverwood Park: Upstream from the Ciba-Geigy Site
2 = Rte. 571 Bridge: Upstream from the Ciba-Geigy Site
3 = Oakridge Parkway Bridge: Immediately downstream from the Ciba-Geigy cooling water discharge
4 = Cadillac Drive: Downstream from the Ciba-Geigy Site
5 = Rte. 37 Bridge: Downstream from the Ciba-Geigy Site

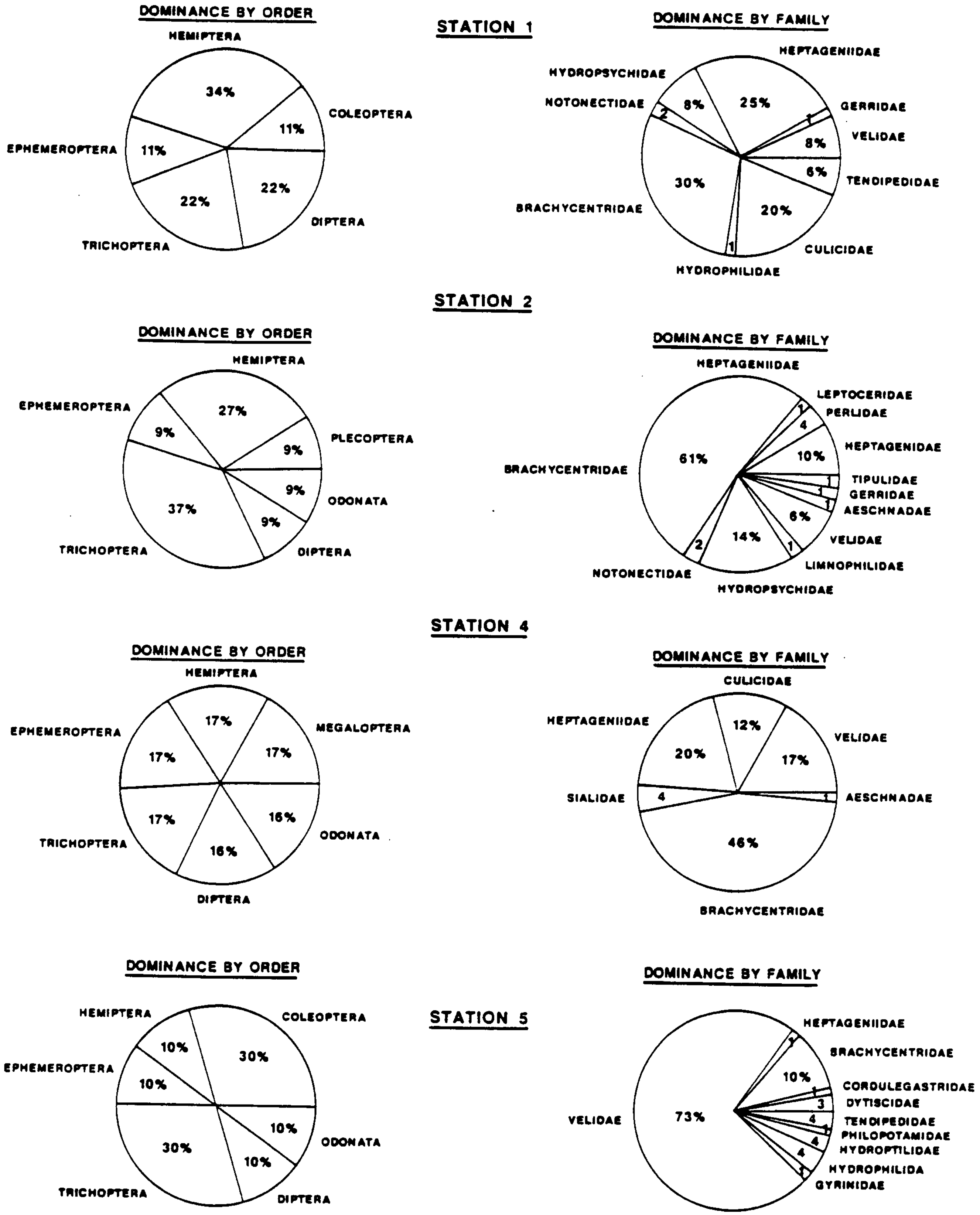


FIGURE 7-4

AQUATIC INSECT POPULATIONS FOUND
IN THE TOMS RIVER, TOMS RIVER, NEW JERSEY
DIPNET SAMPLES COLLECTED JULY 23-24, 1985

NUS CORPORATION

7.3.3 Crab Sampling Results

The blue crab, Callinectes sapidus, was proposed as an indicator species for migration and subsequent bioaccumulation of contaminants potentially transported from the Ciba-Geigy Site to the waters of the Toms River and Barnegat Bay.

Blue crab sampling was conducted by NUS Corporation Region 2 FIT on July 24, 1985, in the estuarine section of the river. Sampling stations were located at equal distances along a transect beginning at the saltwater-freshwater interface of the upper estuary to the point where the Toms River enters Barnegat Bay. Sample collection techniques employed standard crab pots, hand traps, and trot lines.

Efforts to collect blue crabs in the upper and middle reaches of the Toms River estuary were unsuccessful. At the same time however, blue crabs were plentiful and easily caught at the confluence of the Toms River and Barnegat Bay, with the capture of 17 large adult crabs recorded. Euryhaline conditions in the upper reaches of the Toms River estuary reduces the suitability of these waters as habitat for the blue crab. The distance from the Ciba-Geigy Site at which significant crab populations were encountered precludes the use of the blue crab as an indicator species.

Barium

The detected concentrations of barium did not exceed the MCL and no contaminant source was identified based on these groundwater sampling results.

Cadmium

Concentrations of cadmium exceeding the MCL were detected in both on-site (5.3 - 53 ug/L) and off-site (5 - 345 ug/L) downgradient wells. These concentrations pose some risk to the aquifer; however, a contaminant source could not be identified. Concentrations of cadmium were detected in only one upgradient well (RI-24XD). This concentration (11.7 ug/L) exceeds the MCL.

Chromium

Concentrations of chromium exceeding the MCL have been detected on site (1 - 318 ug/L) and off site (10 - 169 ug/L) downgradient wells. Because chromium detected in upgradient wells (10 - 43 ug/L), is significantly less than in downgradient wells the source(s) of chromium groundwater contamination probably exists on site.

Lead

Concentrations exceeding the MCL for lead have been detected in on-site (5.2 - 288 ug/L) and off-site (5.4 - 328 ug/L) wells downgradient from the site. Concentrations of lead exceeding the MCL have been detected in upgradient wells (13.4 - 197 ug/l). No source area for lead contamination was identified based on these groundwater sampling events.

Mercury

Concentrations of mercury exceeding the MCL have been detected in both on-site (.3 - 12 ug/L) and off-site downgradient wells (.2 - 3 ug/L). Concentrations of mercury detected in upgradient wells are below the MCL (.2 - .91 ug/L) and therefore the source(s) of mercury contamination may exist on site.

Selenium

Selenium was detected twice in well RI-9 (6 - 31 ug/L) at concentrations above the MCL. No source area can be identified from this single occurrence.

Silver

Silver was detected at one location off site (3 ug/l). The concentration was below the MCL, and a source area could not be determined from this occurrence.

The data do suggest that inorganic contamination is occurring at the site. As Figure 4-28 displays, the upgradient wells RI-25, RI-26, and RI-27 have lead contamination exceeding the MCL. The upgradient well RI-24XD has cadmium contamination as well as lead. Downgradient wells have cadmium, chromium, lead, mercury, and selenium contamination exceeding the MCLs, and in some cases, at significantly higher levels than upgradient wells. This suggests that inorganic contamination of groundwater is occurring at Ciba-Geigy. An analysis of the distribution and concentrations of these contaminants does not indicate where the on-site source(s) of inorganic groundwater contamination are located.

Inorganic groundwater contamination is consistent with contaminants found in waste source areas and in surface soil. Chapter 3 has already discussed where inorganic contamination was found in the source areas. Briefly, these studies included analytical analysis of sludges and subsurface soils. The results from the analytical analysis revealed that chromium, lead, and mercury were commonly detected at concentrations above background. Chapter 5 will discuss the inorganic contamination found during the surface soil investigation. Briefly, the surface soil investigation was concentrated on soils at depths no greater than 6 inches and in areas where activity may have contaminated the surface soil. Mercury and copper were the most commonly detected inorganic contaminants which had levels that exceeded background. In both studies other inorganic contaminants were identified and the appropriate section should be referenced for greater detail. However, the presence of inorganic contamination in surface soils and source areas supports the conclusion that the Ciba-Geigy Site is loading inorganic contaminants to the groundwater.

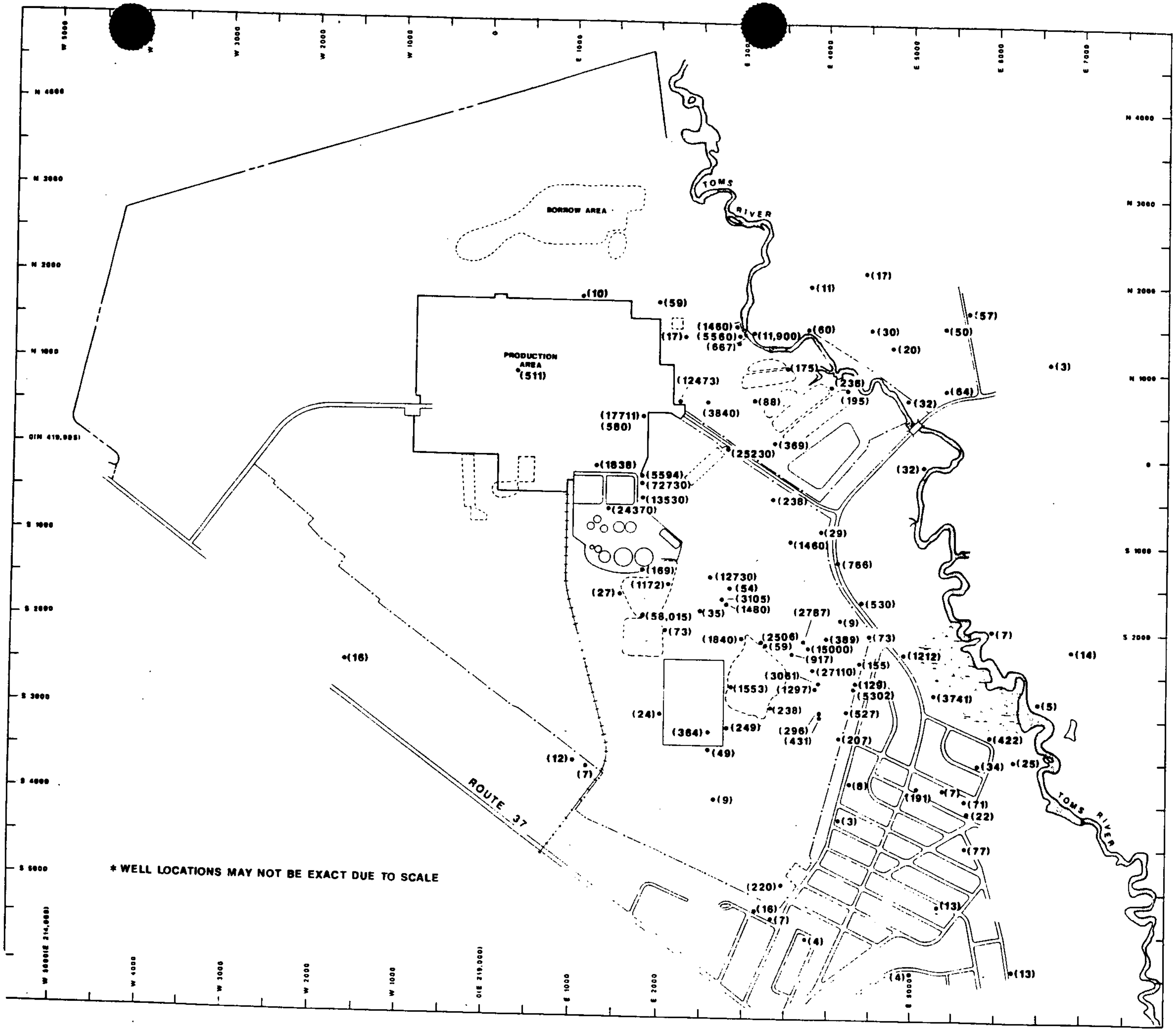
Results of Organic Analysis

Analysis of volatile organic data yields more conclusive results than inorganic analysis. The plotted TVPPs enable the identification of three contaminant source areas and the probability of a fourth area (Figure 4-29, Table 4-11). The three identified source areas are the Wastewater Treatment Plant (WWTP) and southeast Production Area, the Drum Disposal Area, and the Filtercake Disposal Area. The possible fourth source area is the Backfilled Lagoons Area. TVPPs also enable the determination of contamination extent.

Source Areas

The WWTP and southeast corner of the Production Area act as an apparent source of groundwater contamination. The difference in the contaminant concentrations between upgradient and downgradient wells indicates that groundwater is being contaminated at the WWTP (Table 4-11). Well 132, a downgradient well, to the north of the WWTP, is also contaminated. However, 1,2-Dichloroethene and 1,1,1-Trichloroethane are found in well 132 but not in well 133 or 134. Also, wells 133 and 134 have detectable levels of Chlorobenzene which is not found in well 132. Because of the difference in contaminants detected in well 132 as opposed to wells 133 and 134, there are likely to be two contaminant sources. These source areas must be physically close together in the area of the WWTP and the southeastern corner of the Production Area. All of these wells are screened between 21 feet MSL and 27 feet MSL limiting information on the vertical extent of contamination.

The Drum Disposal Area is another apparent source of groundwater contamination. The three downgradient wells are all screened between 10 and 0 feet MSL. Well 109 is screened between -10 and -18 feet MSL. During removal of well 111 (AWARE, 1986), it was observed that the PVC casing had been perforated above the water table aquifer, beginning at a depth roughly coincident with the top of a clay unit. A graunular, asphalt-like material appears to have flowed through the



MAXIMUM DETECTED TOTAL VOLATILE PRIORITY POLLUTANTS (TVPP)

LEGEND

┼─┼─┼	RAILROAD SPUR
—·—·—	SURVEYED BOUNDARY
—··—··—	BOUNDARY FENCE
--------	BOUNDARY ROAD
• (34)	TVPP (ug/L)

FIGURE 4-29

NUS CORPORATION

TABLE 4-11
TVPP CONCENTRATIONS IN UPGRADIENT VERSUS DOWNGRADIENT WELLS BY SOURCE AREA

WWTP and Southeast Production Area

Upgradient Wells	TVPPs (ug/L)	Event	Downgradient Wells	TVPPs (ug/L)	Event
163	0	TRC-06	132	1838	TRC-06
	0	TRC-20		0	TRC-25
	0	TRC-21			
	0	TRC-22	133	72730	TRC-06
	0	TRC-25		7937	TRC-20
				3199	TRC-21
				3170	TRC-22
				0	TRC-25
			134	13530	TRC-06
				4570	TRC-19
				4212	TRC-21
				3820	TRC-22
				2842	TRC-22
				0	TRC-25
			164	5594	TRC-06
				473	TRC-19
				315	TRC-22
				109	TRC-21
				103	TRC-20
			135	24370	TRC-19
				0	TRC-06

Drum Disposal Area

Upgradient Wells	TVPPs (ug/L)	Event	Downgradient Wells	TVPPs (ug/L)	Event
109	27	TRC-29	110A	169	TRC-29
	22	TRC-26		41	TRC-26
	1	TRC-28		20	TRC-27
	0	TRC-06		19	TRC-28
	0	TRC-25		14	TRC-06
	0	TRC-27		0	TRC-05
			108A	1172	TRC-28
				1168	TRC-17
				1089	TRC-29
				1064	TRC-18

TABLE 4-11 (CONT'D)
TVPP CONCENTRATIONS IN UPGRADIENT VERSUS DOWNGRADIENT WELLS BY SOURCE AREA

Drum Disposal Area (Cont'd)

Upgradient Wells	TVPPs (ug/L)	Event	Downgradient Wells	TVPPs (ug/L)	Event
			108A (Cont'd)	654	TRC-15
				644	TRC-26
				442	TRC-27
				119	TRC-06
			111	58015	TRC-16
				58015	TRC-27
				53721	TRC-06
				48200	TRC-15
				48200	TRC-26
				23937	TRC-09
				10919	TRC-28
				10145	TRC-17
				1040	TRC-18
				1005	TRC-29
				835	NUS-25

Filtercake Disposal Area

Upgradient Wells	TVPPs (ug/L)	Event	Downgradient Wells	TVPPs (ug/L)	Event
101A	0	TRC-06	140	27110	TRC-06
102A	24	TRC-06	142	238	TRC-06
	13	TRC-30			
	8	TRC-32	155	10445	TRC-06
	4	TRC-31		10332	TRC-15
	0	TRC-33		9024	TRC-16
				3733	TRC-17
103	0	TRC-06		2361	TRC-18
122	0	TRC-06	167	97	TRC-06
	0	TRC-30		93	TRC-15
	0	TRC-31		78	TRC-18
	0	TRC-32		7	TRC-16
	0	TRC-33	157	295	TRC-06

TABLE 4-11 (CONT'D)
TVPP CONCENTRATIONS IN UPGRADIENT VERSUS DOWNGRADIENT WELLS BY SOURCE AREA

Filtercake Disposal Area (Cont'd)

Upgradient Wells	TVPPs (ug/L)	Event	Downgradient Wells	TVPPs (ug/L)	Event
104	1553	TRC-06	156	1297	TRC-06
105	249	TRC-06	139	917	TRC-06
106	35	TRC-06			
			141	15000	TRC-06
	12	TRC-30			
	0	TRC-31			
	0	TRC-32			
	0	TRC-33			
161	1840	NUS-25			
	1591	TRC-21			
	1460	TRC-17			
	1375	NUS-06			
	1280	TRC-15			
	1250	TRC-06			
	922	TRC-18			
	787	TRC-16			
	460	NUS-05			
168	51	TRC-18			
	10	TRC-06			
	4	TRC-15			
	3	TRC-16			

Backfilled Lagoons

Upgradient Wells	TVPPs (ug/L)	Event	Downgradient Wells	TVPPs (ug/L)	Event
176	88	TRC-03	115	25560	TRC-06
	78	NUS-04		22337	TRC-03
				18130	TRC-09
				17000	NUS-04

TABLE 4-11 (CONT'D)
TVPP CONCENTRATIONS IN UPGRADIENT VERSUS DOWNGRADIENT WELLS BY SOURCE AREA

Backfilled Lagoons (Cont'd)

Upgradient Wells	TVPPs (ug/L)	Event	Downgradient Wells	TVPPs (ug/L)	Event
			124	175	TRC-06
				44	NUS-25
				0	TRC-35
			125	0	TRC-06
				0	TRC-34
				0	TRC-35
			126	0	TRC-06
				0	TRC-34
				0	TRC-35
			127	0	TRC-06
				0	TRC-34
				0	TRC-35
			128	195	TRC-09
				147	TRC-06
			129	0	TRC-06

perforation(s) and down the well casing, stained the casing's interior and collected in the lower 3.5 feet of the well screen. A sample was collected and submitted for priority pollutants +40 analysis (Table 3-7). The results suggest that nonaqueous phase liquids (NAPLs) or sludge may be present in the vicinity of well 0111; however, it has not been determined at this time if this material is below the water table or if it is restricted above shallow clay units. However, with or without NAPL migration, the Drum Disposal Area is a source of groundwater contamination as indicated by the results from wells 108A, 109, 110A.

The Filtercake Disposal Area is also a source of groundwater contamination. Wells 101A, 102A, 103, 104, 105, 106, 122, 161, and 168 are all upgradient and exhibit low to no TVPPs with the exception of wells 104 and 161 which had detected levels of TVPPs up to 1840 ug/L. Wells 140, 141, 142, 157, 156, 155, 167, and 139 are all downgradient of the Filtercake Disposal Area and exhibit TVPPs up to 27,110 ug/L. The location of wells 104 and 161, which are along the western edge of the Filtercake Disposal Area, may explain the elevated TVPPs detected in these wells. Based upon the tenfold increase in TVPP concentration from upgradient to downgradient wells, the Filtercake Disposal Area is determined to be a contamination source.

The Backfilled Lagoons Area also has some indications of being a source area. During September/October of 1985, and January/February of 1986 wells along the eastern edge of the Backfilled Lagoons Area were sampled. The results revealed contamination in the shallow wells (13 feet MSL) but none in the deep wells (-37 feet MSL). Subsequent sampling and analysis during 1986 did not reveal any TVPP contamination; however, wells 115 and 128, which had detected levels of TVPP contamination as high as 25,000 ug/L during the first of sampling, were not resampled in 1986. The difference in TVPP concentrations between samplings is probably the result of minor groundwater variations or poor sampling techniques.

4.5.3 Summary of Groundwater Quality Investigation

The following section discusses the conclusions of the groundwater quality investigation as they relate to program objectives.

Waste Source Areas

Six potential waste source areas were investigated by GPR profiling, and to a limited extent by EM surveying. Each area investigated by GPR contains at least one location where detected anomalies may be disturbed soils (i.e., landfill or excavation) or point sources (i.e., drums). In some cases, the boundaries of the anomaly could be determined, but because of the limited number of profiling lines completed, more work is required before accurate volumetric calculations can be done. The areas in which anomalies were most evident are the Backfilled Lagoons, Filtercake Disposal Area, Drum Disposal Area, and the Suspected East Overflow Area. The EM survey has identified these areas and also the WWTP, Former Fire Prevention Area, Lime Sludge Disposal Area, and the Active Landfill as potential contaminant sources. Other areas identified by GPR as potential sources are the Casual Dumping Area and the Borrow Area. These areas were also surveyed using EM methods; however, only background results were observed. The discrepancy between data sets indicates that additional work may be required to verify the existence of possible contaminant point sources.

Groundwater sampling identifies three contaminant source areas: the WWTP and Southeast Production Area, Drum Disposal Area, and Filtercake Disposal Area. The Backfilled Lagoons Area requires further investigation as a potential contaminant source.

Contaminant Plumes

Conclusions regarding inorganic contamination associated with the site were based on MCLs and upgradient versus downgradient concentrations, while organic contamination was defined using TVPPs. Both were limited by three factors:

- Spatial distribution of wells is not systematic. Monitoring wells at the Ciba-Geigy Site have been installed over a 28-year period. During this time, conceptions of site geology and contaminant migration have changed. Therefore, many wells are not ideally placed in relation to source areas or lithologic and hydrogeologic units.
- Depths of many residential wells are unknown. Although residential wells containing contaminants attributable to the site are useful in defining the horizontal extent of contamination, they may be of little help in determining the vertical distribution of contaminants. Caution must be used in concluding that groundwater beneath a residential area is "clean" because nondetection of contaminants may simply be a result of not having wells screened in a contaminated depth interval.
- Most sampling has been conducted without a sitewide sampling strategy. Initial sampling was often oriented toward source characterization as costs for comprehensive sampling could be prohibitive. Later sampling has focused more on the lateral extent of contamination especially in residential areas, but this sampling has precluded resampling of some wells near source areas.

The contoured EM data provide a first approximation of the lateral extent of the groundwater contaminant plume. To refine the EM plume model, it is necessary to compare electromagnetic conductivity measurements with split-spoon samples, groundwater specific conductance, and the total concentration of metal ions in groundwater samples. To support and refine the interpreted EM plume, total volatile priority pollutants (TVPP) were calculated from groundwater samples and used instead of the concentration of metal ions. TVPPs were chosen because of the natural metal content of groundwater, the relative immobility of metal contaminants, and because TVPPs are a major contaminant problem. Table 4-12 compares groundwater analytical results (TVPP and specific conductance) and EM conductivity measurements.

Normally, electromagnetic conductivity is not sensitive to varying concentrations of volatile organic compounds. However, EM values obtained at several locations on site are in good agreement with TVPP values (Table 4-12). The 5 millimhos per meter contour (Figure 4-30) is the extent of the contaminant plume as defined by EM and agrees with the plume boundary defined by TVPP data. The TVPP contaminant plume boundary has been tentatively identified using a 5 ug/L concentration contour. This contour indicates that contaminants have migrated east of the Toms River and the Cardinal Drive Community.

The eastern contaminant plume boundary is fairly continuous as defined by the interpolated 5 mmhos/m contour using VDM and HDM data. Levels of higher conductivity are discontinuous across the site and appear to extend through two major areas: the northernmost Backfilled Lagoon and Former Fire Prevention Area, and the collective areas of the Wastewater Treatment Plant, Drum Disposal Area, Lime Sludge Disposal Area, and the Filtercake Disposal Area. These node areas of elevated conductivity are potentially the major contributors to groundwater contamination. Because of EM data limitations, the Active Landfill, southernmost Backfilled Lagoons, and the Emergency Storage Reservoir could not be directly implicated as source areas. EM surveys were not conducted in the Production Area because of potential interference created by manufacturing structures, but at least part of this area is implicated as a potential groundwater contamination source based on TVPP concentrations.

Data deficiencies limit the interpretation of the contaminant plume in three areas; west of the Production and Casual Dumping Area; east of the Toms River and north of monitoring well location RI-13; and south and east of monitoring well location RI-1. The 5 ug/L contour was drawn as a dotted line to indicate the data deficient areas of the contaminant plume. In the area of RI-13, EM survey data was used to estimate the extent of contamination using the assumption that EM survey data is a less sensitive indicator of contamination than groundwater sample analysis.

TABLE 4-12

COMPARISON OF EM VALUES, TVPP CONCENTRATIONS, AND GROUNDWATER SPECIFIC CONDUCTANCE

EM Survey Line No.	Interpreted EM Value (mmhos/m)	Monitoring Well No.	Monitoring Well Depth	TVPP (ug/L)	Date	Groundwater Specific Conductance Value (umhos/cm)	Date
1	3 to 6_H	RI-1S	19.0	0	8/85	164	8/85
		RI-1D	37.0	0	8/85	85	8/85
		RI-1XD	69.5	25	6/86	42	6/86
	10 to 16_H	RI-4-S	45.0	618	2/86	950	6/86
		RI-4D	82.5	3741	8/85	1780	8/86
	6 to 19_H	RI-5S	35.0	1064	9/86	170	6/86
		RI-5D	67.0	1212	2/86	700	6/86
4	6 to 7_V	RI-31S	47.5	7	9/86	380	6/86
		RI-31D	92.0	59	2/86	340	6/86
	5_V	0146	51.5	0	9/85	63	9/85
5	2 to 5_V	RI-19S	39.0	17	8/85	109	8/86
		RI-19D	54.0	5	8/85	129	8/86

All wells screened in upper sand unit unless otherwise noted.

Interpreted EM Value - Indicates the EM value at the given well site, or if a well is not available, a value is given for the survey line in general.

Subscript V,H indicates EM instrument orientation, V - Vertical, H-Horizontal.

TVPP - Total Volatile Priority Pollutant, maximum concentrations taken from sampling dates August 1985 to November 1986.

NA - Not Available

TABLE 4-12 (CONT'D)

COMPARISON OF EM VALUES, TVPP CONCENTRATIONS, AND GROUNDWATER SPECIFIC CONDUCTANCE

EM Survey Line No.	Interpreted EM Value (mmhos/m)	Monitoring Well No.	Monitoring Well Depth	TVPP (ug/L)	Date	Groundwater Specific Conductance Value (umhos/cm)	Date
6	20 to 25_{V}	0111	54.0	58015	5/86	170	11/86
8	12 to 16_{V}	RI-16	75.2	29	6/86	368	6/86
9	3 to $5_{V,H}$	RI-8	34.5	60	9/86	100	6/86
	8 to $12_{V,H}$	RI-9	24.0	11900	9/86	800	6/86
9A	8 to $10_{V,H}$	RI-17	34.5	1460	6/86	320	6/86
	$5_{V,H}$	RI-29S	32	0	8/85	51	8/85
	$5_{V,H}$	RI-29D	69	0	8/85	52	8/85
10	$5_{V,H}$	RI-6	37.5	32	2/86	98	8/85
	$5_{V,H}$	RI-7	32.0	0	8/85	55	8/85

All wells screened in upper sand unit unless otherwise noted.

Interpreted EM Value - Indicates the EM value at the given well site, or if a well is not available, a value is given for the survey line in general.

Subscript V,H indicates EM instrument orientation, V - Vertical, H-Horizontal.

TVPP - Total Volatile Priority Pollutant, maximum concentrations taken from sampling dates August 1985 to November 1986.

NA - Not Available

TABLE 4-12 (CONT'D)

COMPARISON OF EM VALUES, TVPP CONCENTRATIONS, AND GROUNDWATER SPECIFIC CONDUCTANCE

EM Survey Line No.	Interpreted EM Value (mmhos/m)	Monitoring Well No.	Monitoring Well Depth	TVPP (ug/L)	Date	Groundwater Specific Conductance Value (umhos/cm)	Date
	$5_{V,H}$	0129	68.0	0	9/85	NA	
	$5_{V,H}$	0126	20.5	236	9/85	NA	
	$5_{V,H}$	0127	67.0	0	9/85	NA	
	$5_{V,H}$	RI-10S	37.2	18	6/86	109	8/85
		RI-10D	76.0	30	10/85	64	10/85
	$5_{V,H}$	RI-11S	33.0	5	6/86	250	6/86
		RI-11D	70.0	20	10/85	103	10/85
11	3 to 5_H	RI-2S	8.0	5	8/85	139	8/85
		RI-2D	17.5	0	8/85	103	8/85
		RI-2XD	53.0	0	8/85	68	8/85
	3 to 5_H	RI-3S	31.55	14	6/86	160	6/86
		RI-3D	52.5	6	6/86	210	6/86
		*RI-3XD	177.0	0	10/85	335	10/85

All wells screened in upper sand unit unless otherwise noted.

*Well screened in silt and clay unit.

Interpreted EM Value - Indicates the EM value at the given well site, or if a well is not available, a value is given for the survey line in general.

Subscript V,H indicates EM instrument orientation, V - Vertical, H-Horizontal.

TVPP - Total Volatile Priority Pollutant, maximum concentrations taken from sampling dates August 1985 to November 1986.

NA - Not Available

TABLE 4-12 (CONT'D)

COMPARISON OF EM VALUES, TVPP CONCENTRATIONS, AND GROUNDWATER SPECIFIC CONDUCTANCE

EM Survey Line No.	Interpreted EM Value (mmhos/m)	Monitoring Well No.	Monitoring Well Depth	TVPP (ug/L)	Date	Groundwater Specific Conductance Value (umhos/cm)	Date
	3 to 5_H	RI-12S RI-12D	28.6 48.0	0 0	8/85 8/85	110 89	8/85 8/85
	3 to 5_H	RI-13S RI-13D	21.0 44.2	7 6	9/86 6/86	190 50	6/86 6/86
12	2 to 7_V	0110	57.0	169	11/86	170	11/86
13	8 to $12_{V,H}$	0124	25.8	175	9/85	N/A	
	4 to $7_{V,H}$	0115	67.0	25560	10/85	1730	10/85
	8 to $10_{V,H}$	RI-17	35.4	1460	6/86	320	6/86
14	5_H	RI-14S RI-14D	28.0 63.5	19 530	9/86 2/86	110 140	6/86 6/86

All wells screened in upper sand unit unless otherwise noted.

Interpreted EM Value - Indicates the EM value at the given well site, or if a well is not available, a value is given for the survey line in general.

Subscript V,H indicates EM instrument orientation, V - Vertical, H-Horizontal.

TVPP - Total Volatile Priority Pollutant, maximum concentrations taken from sampling dates August 1985 to November 1986.

NA - Not Available

TABLE 4-12 (CONT'D)

COMPARISON OF EM VALUES, TVPP CONCENTRATIONS, AND GROUNDWATER SPECIFIC CONDUCTANCE

EM Survey Line No.	Interpreted EM Value (mmhos/m)	Monitoring Well No.	Monitoring Well Depth	TVPP (ug/L)	Date	Groundwater Specific Conductance Value (umhos/cm)	Date
	5_H	RI-15S	40.0	17	2/86	58	8/85
		RI-15D	73.6	766	9/86	850	8/85
16	3 to 5_V	RI-27S	57.0	0	10/85	101	10/85
		RI-27D	103.0	0	10/85	43	10/85
	3 to 5_V	1100	110	0	4/86	NA	
17	5 to 10_H 12 to 20_V	0131	72.0	25230	10/85	19150	10/85
N/A	N/A	0132	N/A	1838	9/85		
N/A	N/A	RI-23S	74	0	10/85	122	10/85
		RI-23D	98.5	0	6/86	98	10/85

All wells screened in upper sand unit unless otherwise noted.

Interpreted EM Value - Indicates the EM value at the given well site, or if a well is not available, a value is given for the survey line in general.

Subscript V,H indicates EM instrument orientation, V - Vertical, H-Horizontal.

TVPP - Total Volatile Priority Pollutant, maximum concentrations taken from sampling dates August 1985 to November 1986.

NA - Not Available

TABLE 4-12 (CONT'D)

COMPARISON OF EM VALUES, TVPP CONCENTRATIONS, AND GROUNDWATER SPECIFIC CONDUCTANCE

EM Survey Line No.	Interpreted EM Value (mmhos/m)	Monitoring Well No.	Monitoring Well Depth	TVPP (ug/L)	Date	Groundwater Specific Conductance Value (umhos/cm)	Date
NA	NA	RI-24S	65	0	10/85	88	10/85
		RI-24D	88	0	10/85	119	10/85
NA	NA	0183	100	511	1/86	480	1/86
NA	NA	0185	73	64	11/86	100	1/86
NA	NA	0187	77	49	10/86	87	1/86
NA	NA	0191	72	17	10/86	60	1/86
3	5_V	1106	102	10	4/86	NA	
NA	NA	RES17	NA	13	4/85	NA	
NA	NA	RES18	NA	7	4/85	NA	
NA	NA	RES19	80	16	4/85	NA	

All wells screened in upper sand unit unless otherwise noted.

Interpreted EM Value - Indicates the EM value at the given well site, or if a well is not available, a value is given for the survey line in general.

Subscript V,H indicates EM instrument orientation, V - Vertical, H-Horizontal.

TVPP - Total Volatile Priority Pollutant, maximum concentrations taken from sampling dates August 1985 to November 1986.

NA - Not Available

TABLE 4-12 (CONT'D)
COMPARISON OF EM VALUES, TVPP CONCENTRATIONS, AND GROUNDWATER SPECIFIC CONDUCTANCE

EM Survey Line No.	Interpreted EM Value (mmhos/m)	Monitoring Well No.	Monitoring Well Depth	TVPP (ug/L)	Date	Groundwater Specific Conductance Value (umhos/cm)	Date
NA	NA	RES20	57	4	4/85	NA	
NA	NA	RES21	65	4	4/85	NA	
NA	NA	RES24	35	0	4/85	NA	
NA	NA	RES25	NA	0	4/85	NA	
NA	NA	RES26	NA	7	4/85	NA	
NA	NA	RES27	60	12	4/85	NA	
NA	NA	RES28	100	3	4/85	NA	
NA	NA	RES29	NA	0	4/85	NA	
NA	NA	RES30	NA	13	4/85	NA	

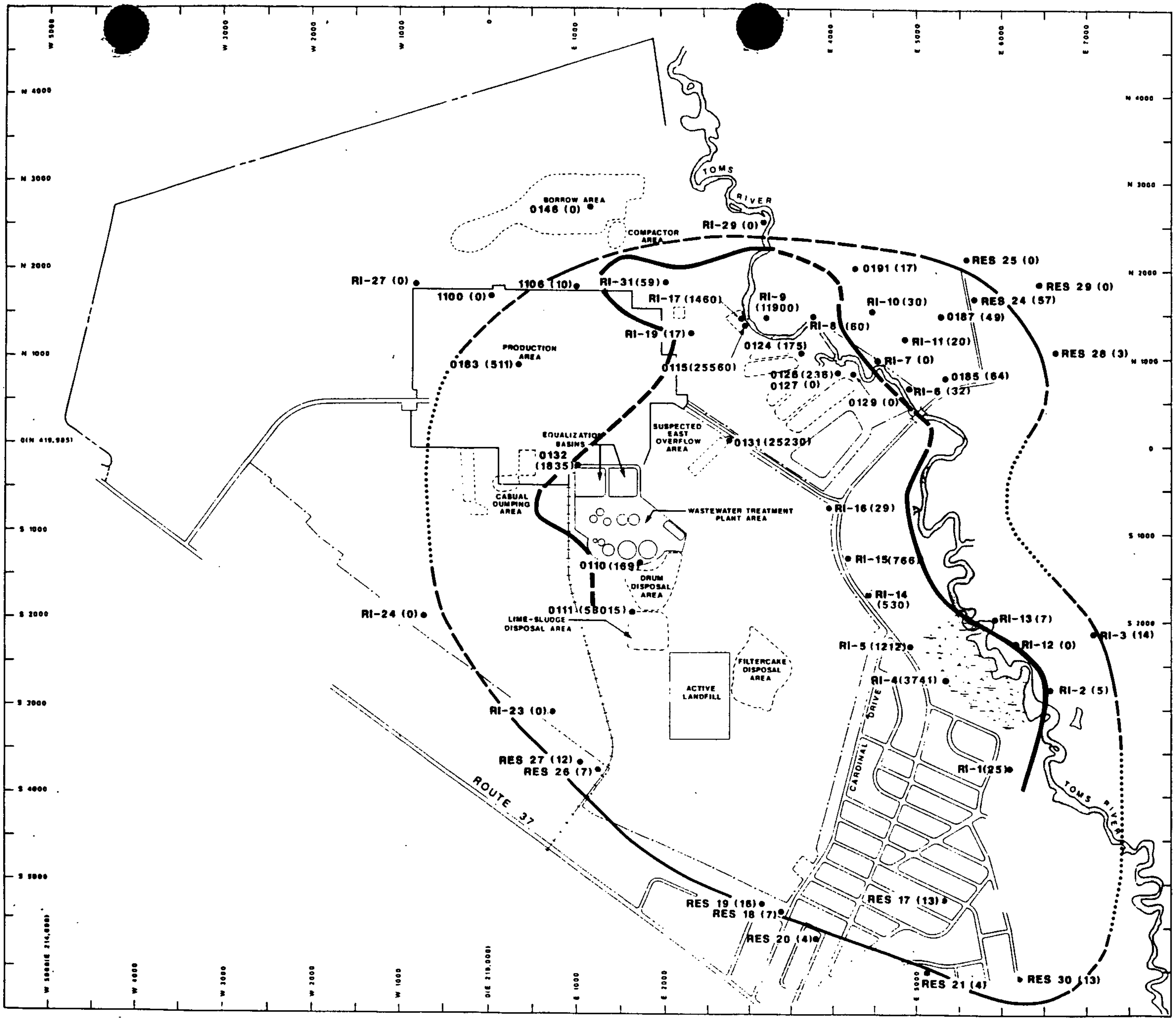
All wells screened in upper sand unit unless otherwise noted.

Interpreted EM Value - Indicates the EM value at the given well site, or if a well is not available, a value is given for the survey line in general.

Subscript V,H indicates EM instrument orientation, V - Vertical, H-Horizontal.

TVPP - Total Volatile Priority Pollutant, maximum concentrations taken from sampling dates August 1985 to November 1986.

NA - Not Available



APPROXIMATE LATERAL EXTENT TVPP CONTAMINATION > 5 ug/L AND ELECTROMAGNETIC CONDUCTIVITY CONTOURS >5 MILLIMHOS/M

LEGEND

—+—+— RAILROAD SPUR
—·-·— SURVEYED BOUNDARY
-·—·- BOUNDARY FENCE
------- BOUNDARY ROAD
——— APPROXIMATE LIMIT OF 5ug/L CONTOUR
— — — APPROXIMATE LIMIT OF 5ug/L CONTOUR-INFERRED
········ APPROXIMATE LIMIT OF 5ug/L CONTOUR-LIMITED DATA
━━━ 5 millimhos/m ELECTROMAGNETIC CONTOUR
━ ━ ━ INFERRED 5 millimhos/m ELECTROMAGNETIC CONTOUR
●RES 28 (6)-WELL NUMBER (TVPP)

NOTE:
TVPP VALUES SHOWN ARE MAXIMUMS FOR THE UPPER SAND UNIT

FIGURE 4-30

NUS CORPORATION

4.6 Conclusions

The conclusions drawn from analysis of hydrogeologic characteristics and groundwater contamination studies at the site are as follows:

1) The investigation identified two aquifers at the site which are separated by a semiconfining unit with a vertical hydraulic conductivity of approximately 1.0×10^{-5} cm/sec. Although Zapecza (1984) describes the Kirkwood Formation and Cohansey Sand as a single aquifer regionally, two aquifers at the site are delineated based on

   - Differential head
   - Interaction with the Toms River

   The upper sand aquifer has a horizontal hydraulic conductivity of approximately 9.8×10^{-3} cm/sec and extends downward to at approximately -100 feet MSL. The silt and clay semiconfining unit varies between approximately 30 and 60 feet in thickness, with the top of the unit at approximately -100 feet MSL. This unit has a vertical hydraulic conductivity of 1.0×10^{-5} cm/sec. The lower sand aquifer dips east-southeast and has a hydraulic conductivity of 5.2×10^{-3} cm/sec.

2) Clay beds within the upper sand unit are discontinuous and may act as confining units only in localized areas within the site.

3) Groundwater flow direction in the lower sand aquifer is primarily east and southeast. The Toms River apparently has no effect on the lower aquifer; however, this is not conclusively determined because there is a lack of wells on the east side of Toms River that are screened in the lower aquifer.

4) Groundwater flow in the upper sand aquifer is strongly influenced by the Toms River which acts as a sink. Groundwater flow at the site is primarily eastward toward the river. Flow on the east side of the river is primarily westward. Contaminants entering the groundwater system at

the Production Area, Drum Disposal Area, Wastewater Treatment Plant, or Equalization Basins tend to descend initially, then rise in the discharge area closer to the river. This behavior may cause apparent anomalies in the extent of contaminant plumes.

5) Groundwater sampling has been sufficient to establish that the Ciba-Geigy Site is contributing significant amounts of volatile organic and inorganic contaminants to the groundwater. Three contaminant source areas are identified on site: the WWTP and Southeast Production Area, Drum Disposal Area, and Filtercake Disposal Area. The groundwater contaminant plume originating from the Ciba-Geigy Site is considered to be a composite of several plumes originating from a number of on-site source areas. Contamination has been detected in the Cardinal Drive and Coulter Street areas. The areas south of Coulter Street have not been thoroughly sampled.

6) A combination of factors including higher hydraulic head in water-filled lagoons, periodic river flooding, and an underlying clay layer, combine to provide potential mechanisms for transporting contaminants east of the main river channel. In addition, greater hydraulic head in the lagoon area of the upper sand aquifer may have facilitated transport of potentially contaminated groundwater into the lower sand aquifer. Once contaminants are in the lower sand aquifer, they are subject to transport away from the site and possibly east of the Toms River.

7) Ciba-Geigy purge wells, while intercepting significant quantities of contaminated groundwater, tend to divert potentially contaminated groundwater from the Southeast Production Area into the Cardinal Drive residential area. This groundwater would flow eastward north of the Cardinal Drive residential area under the condition of zero pumping rates at the Ciba-Geigy purge wells.

Topics for further study are:

1) Further defining the three-dimensional extent of contamination along potential contaminant migration routes. This includes the areas southeast of the Production Area toward the Cardinal Drive residential area, the area between Cardinal Drive and Coulter Street, and the area to the northeast and east of the Backfilled Lagoons. Wells should also be installed at several points along the contact between the upper sand unit and silt and clay unit near the Drum Disposal Area to determine the possible existence of NAPL contamination.

2) Determining the role of the Toms River and Toms River valley as a groundwater sink. This would require wells or piezometers at various depths on both sides of the river, but especially along and east of the abandoned river channel near Coulter Street. Emphasis should be placed on determining groundwater flow characteristics in the lower part of the upper sand aquifer (-50 to -100 feet MSL) and the hydraulic properties of the silt and clay semiconfining unit. Additionally, a high density piezometer study should be made in the area near well RI-9 to determine the influence of river meanders and flood events on groundwater flow.

3) Installation of additional wells and boreholes in the northeast portion of the site, south of the Pine Lake Park area, to further constrain lithologic relationships. In addition, a borehole immediately south of the Active Landfill and Filtercake Disposal Area is necessary for lithologic control along this important potential route of contaminant migration.

4) Development of and adherence to a consistent sampling strategy. The matrix of data generated from the samplings must be complete (i.e., all sampling must take place), and the wells to be sampled must represent the areas of interest. The sampling schedule should be maintained until remediation is initiated. The remedial work may also require the continuation of this sampling effort.

5

5.0 SOIL INVESTIGATION PROGRAM

The objective of the surface soil and intermittent stream sediment sampling program was to determine the presence or absence of contamination and contaminant migration around known or suspected waste disposal areas and spill areas and along transportation routes at the Ciba-Geigy Site. Major tasks of the investigation were to

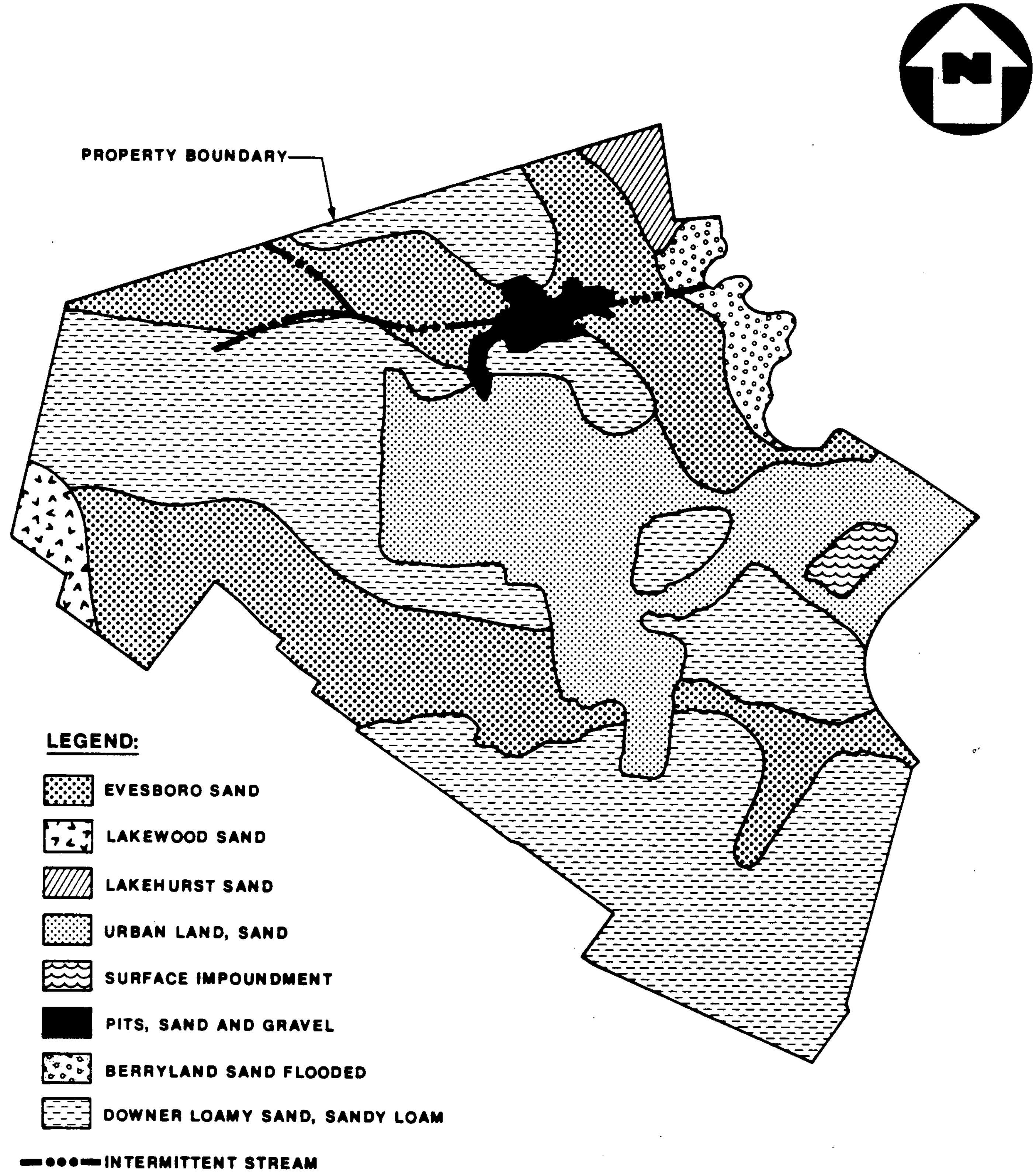
- Define an appropriate background or control region for the Ciba-Geigy Site.
- Delineate and sample areas suspected of being contaminated.
- Determine whether investigation areas are contaminated, and if so, to what extent.

Section 5.1 describes the soil types present on the Ciba-Geigy Site. This knowledge is necessary to fully understand potential soil sorption and migration of contaminants. Section 5.2 explains the sampling strategy and the methods used to analyze the data. Section 5.3 is the analysis of data by the methods explained in Section 5.2. Section 5.4 summarizes the conclusions and recommendations that are based upon the soil investigation.

5.1 Soil Types Present on the Ciba-Geigy Site

The Ciba-Geigy Site is underlain predominantly by two major soil types, the Downer loamy sand and sandy loam, and the Evesboro sand. Berryland, Lakehurst, and Lakewood sands also are present. Soils below developed areas are classified as undifferentiated sands. Figure 5.1 shows the distribution of soil types throughout the site.

Downer soils occur on level to gently sloping areas, and have moderately high permeabilities throughout the profile. Evesboro sands occur on divides and side slopes and are excessively well drained; permeability is high throughout the profile. Berryland sands occur in depressed areas along the Toms River; these soils are very poorly drained and subject to frequent flooding. Lakehurst sands are found on broad, level areas adjacent to streams and depressions where they are moderately well drained, and in depressions and low terraces where they are somewhat poorly drained; soil permeability is high throughout subsoil and



Soil Survey of OCEAN COUNTY, New Jersey
USDA--Soil Conservation April 1980

FIGURE 5.1

NUS CORPORATION

DISTRIBUTION OF SOIL TYPES
CIBA-GEIGY SITE, DOVER TWP., N.J.

SCALE : 1"=1486'

substratum. Lakewood sands occur in level areas or on gently sloping side slopes and divides, and are excessively well drained; permeability is high in surface and subsurface horizons, and moderate in the substratum.

Evesboro, Lakehurst, Lakewood, and Berryland soils are formed on previously eroded coarse-grained sands of the Cohansey Formation. Downer soils are formed upon both the Beacon Hill and Cohansey Formations. All site soils are coarsely textured and moderately to strongly acidic. They are considered to have only limited capacities for attenuating organic or inorganic priority pollutants because of their relatively low clay and organic matter contents.

5.2 Investigation Approach

The technical approach of the Ciba-Geigy soil investigation involved the identification of potential soil contaminant pathways and development of sampling plans to determine the nature and extent of soilborne contamination occurring at the Ciba-Geigy facility. Specific investigation tasks were as follows:

- Define the extent of near-surface contamination around waste disposal areas.
- Define an appropriate background or control region for the site.
- Define the extent of contamination in intermittent stream beds adjacent to known or suspected waste disposal areas.
- Identify the extent of contamination along roadways from uncontrolled spills and dust.
- Identify the presence or absence of 2,3,7,8-TCDD (Dioxin) in soils adjacent to facilities where 2,4,5-trichlorophenol (TCP) was handled or utilized.

Sampling locations were determined by using both random and judgmental methods. Random locations were defined as those locations where a random numbers table was utilized to generate sampling distances and directions from a specified control point or benchmark within the investigation area. Judgmental locations were defined as those locations where a field decision or bias governed the location where each sample was collected. Random sampling was performed based on the assumption that contaminants, if present, are diffuse and that concentrated contaminant areas are absent. Judgmental sampling allowed for the characterization of the contamination in erosional and depositional areas at the Ciba-Geigy Site.

A suitable control area was identified to provide comparisons with potentially contaminated investigation areas. Random and judgmental soil data were evaluated by comparing site-specific background values with investigative sample values for Hazardous Substance List (HSL) parameters. In addition, a Wilcoxon-Mann-Whitney nonparametric test was used to determine whether soil data from the random HSL locations exceeded site-specific background contaminant levels (Freund and Walpole 1980). All samples containing greater than background levels of contaminants were further evaluated to determine their migration potential via air, surface water, and groundwater routes. Sampling precision was evaluated to determine the total random error associated with sampling and analyses. The soil sampling program incorporated statistical designs and QA/QC plans to provide quantitative measures of both precision and representativeness.

The data evaluation process was designed to identify the presence or absence of contamination that exceeds a background level or a prescribed criterion or standard. The process differs depending on whether soil samples were collected at random or judgmental locations and whether standards or criteria exist with which to compare soil contaminant concentrations. Generally, few such standards or criteria exist for soils. However, background contaminant concentrations were determined from the Control Area samples. As a supplement to the Control Area data, inorganic data on median concentrations of contaminants in natural soils were used. This information was taken from data which are representative of New Jersey soils and compiled by Stephen Toth and Harry Motto, Cook College, Rutgers University. Where information was not available on New Jersey soils, national backgrounds were taken from the Agency for Toxic Substances and Disease Registry's (ATSDR) memo titled, "Median elemental composition of soils," issued in October of 1986.

5.2.1 Random Locations

Results from randomly located samples within each of five investigation areas were compared with data from the Control Area using a Wilcoxon-Mann-Whitney (W-M-W) nonparametric test of the hypothesis

$$H: S_X = S_C$$

against the alternative

$$A: S_X \neq S_C$$

where S_C = the true median concentration of any chemical parameter in the Control Area, and S_X = the true median concentration of any chemical parameter in an investigation area. A probability level L = 0.10 was selected to evaluate the hypothesis H of similar median concentrations. H will be accepted unless L is less than 0.10 (i.e., there is a 90 percent probability that the true median concentration of any HSL parameter in any of the five random investigation areas exceeds that in the Control Area).

The W-M-W test must be clearly understood to avoid false interpretations. The W-M-W test is designed to determine whether one set of samples was taken from an area with a different true average contamination level. This means that the test analyzes an area as a whole, not as individual samples. Therefore, although one sample may have an alarmingly high concentration of one contaminant, the W-M-W test may still yield a negative result. This is possible because according to the Normal Distribution, which is part of the basis for the W-M-W test, there is a slight possibility that high values do exist. Hence, the correct interpretation of a result where no difference was yielded is that the area as a whole is not contaminated. This does not preclude the possibility that points within the area may be contaminated.

5.2.2 Judgmental Locations

The first stage of data evaluation for judgmentally located samples was to compare them with background levels identified by the Control Area and state wide soil testing. These data were not used in the W-M-W test because they were located in areas most likely to be contaminated. Using samples that were taken only in areas of likely contaminant locations does not yield a true representation of the whole area. However, this does not prevent the random samples from being included in the analysis of the judgmental samples. The random samples especially help in determining the likelihood of contaminant migration or the extent of contaminant migration away from the localized contaminated areas identified by judgmental samples.

The second stage of the data evaluation process was a prediction of the contaminant migration potential. Soil contaminants may be transferred in air as fugitive dusts, in surface water via erosion, and in groundwater as a result of leaching. Such an evaluation is usually qualitative and requires use of known or estimated soil properties, landscape position, location of contaminant migration routes, distance to potential receptors, and the presence or absence of a contaminant in either surface water, sediment, or groundwater as determined by monitoring.

5.2.3 Determination of Sampling Precision

Every third sample of soil or dry sediment collected for analysis of HSL parameters was a replicate to measure sampling precision. Precision is a measure of the total random error due to both sample collection and analysis, and provides an estimate of the uncertainty of all reported contaminant concentrations.

Precision is calculated as follows:

$$P = \frac{D_{x2-x1}}{X} \times 100$$

Where: P = Precision, in percent

D_{x2-x1} = The concentration difference between a sample and a sample replicate

X = The average contaminant concentration of a sample and a sample replicate.

5.3 Description of Soil Sampling Investigation

A primary component of this sampling program was to identify appropriate areas in which to concentrate the sampling efforts. Review of past waste disposal practices, photographs, site history, topography, and potential contaminant pathways revealed 11 potentially contaminated areas. The following is a list of the investigation areas sampled under the remedial investigation and the method(s) utilized to locate samples within each investigation area:

- Backfilled Lagoons Area - random and judgmental sampling locations.
- Borrow Area - random and judgmental sampling locations.
- Drum Disposal Area/Lime-Sludge Area - random and judgmental sampling locations.
- Production Area (Ciba-Geigy Facilities) - judgmental sampling locations.
- Filtercake Disposal Area - random and judgmental sampling locations.
- Intermittent Drainage Area East of the Wastewater Treatment Plant - judgmental sampling locations.
- Intermittent Drainage Area East of Well No. 400 - judgmental sampling locations.
- Suspected Casual Dumping Area Southwest of Production Facilities - judgmental sampling locations.
- Suspected Overflow Area Northeast of the Wastewater Treatment Plant - random and judgmental sampling locations.

- Transportation Route (Old Roadway) - judgmental sampling locations.
- Transportation Route (Railway) - judgmental sampling locations.

In addition to identifying the 11 potentially contaminated investigation areas, a Control Area was identified and utilized to provide a basis for statistical comparison between data sets.

By definition, a control area for a soil investigation should be close to, but not influenced by, the site being investigated, and should contain similar soil types. Ideally, a control area is impacted by all regional contaminant sources present, such as certain pesticides ubiquitously found in both urban and agricultural soils, but does not contain contaminants generated by the site itself. Comparisons of soil contaminant levels in any of the investigation areas with soil levels in the control area should be capable of clearly separating the influence of the site from the background characteristics of the region.

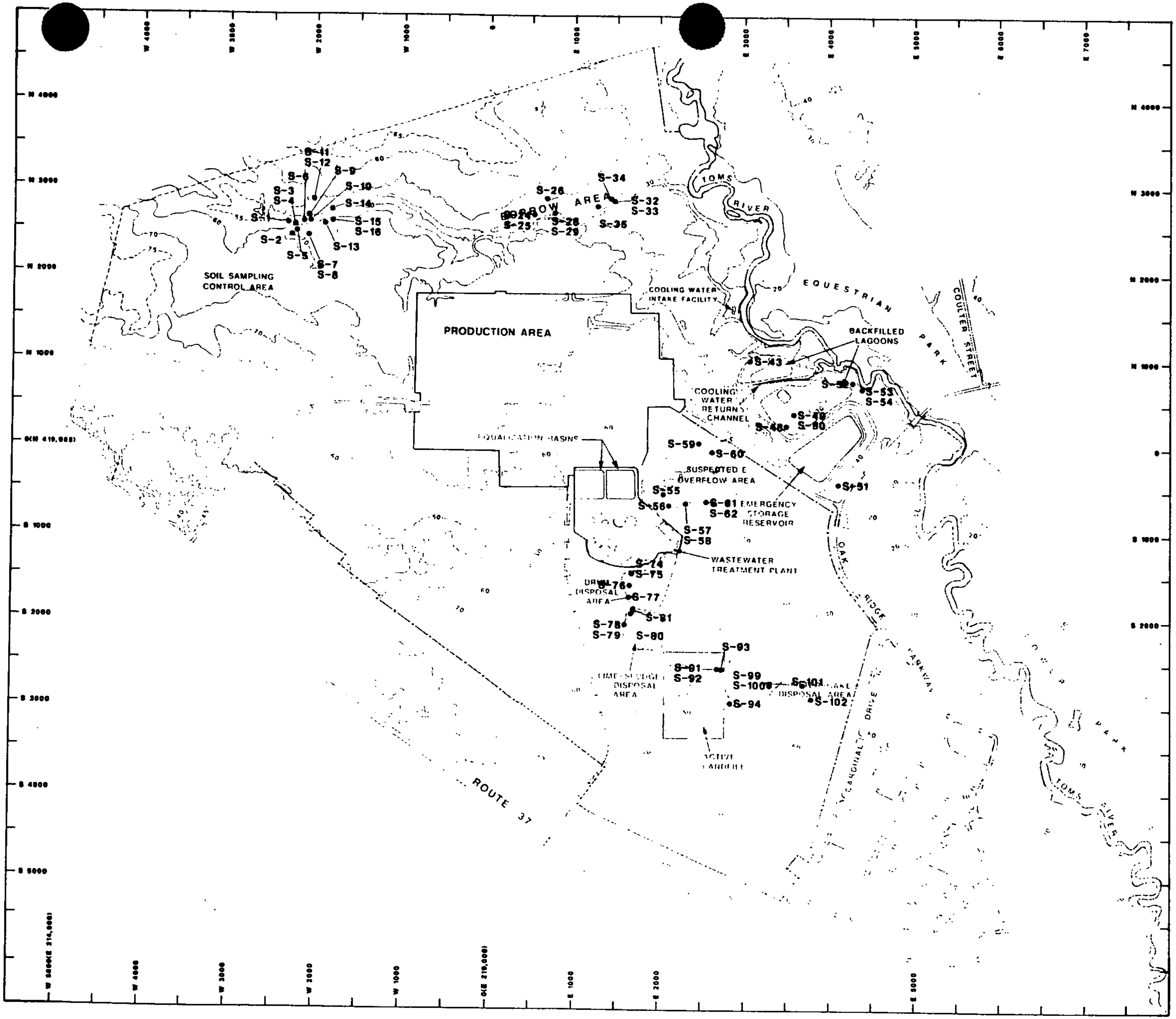
In practice, few ideal control areas exist. Two special problems exist at the Ciba-Geigy facility in locating a control area for surface soils and intermittent stream sediments. First, dry intermittent stream beds unaffected by activity at Ciba-Geigy may not exist on the Ciba-Geigy Site. Second, airborne hazardous substances from the Ciba-Geigy facility may be concentrated to some extent in surrounding surface soils. Since it is unlikely that control areas for transportation routes and intermittent stream beds can be found within the Ciba-Geigy Site, a single Control Area northwest of the active facility that represents surface soil and intermittent stream beds was selected as a background for all surface soils and dry sediment samples collected at the Ciba-Geigy Site (S-1 through S-16). This Control Area's location is displayed on Figure 5-2 where samples S-1 through S-16 were taken. The Control Area selected at the Ciba-Geigy facility adequately fulfills the requirements described above.

5.3.1 Sample Collection and Analysis

All samples were collected from a depth of 0 to 4 inches. The samples were analyzed for HSL parameters, indicator parameters (TOX, TOC, PCBs, and Metals), or 2,3,7,8-TCDD (dioxin), depending upon the source area and sampling approach (random or judgmental) used. All random samples were analyzed for HSL parameters. Judgmental samples were analyzed for HSL parameters, indicator parameters, or dioxin. Indicator parameter samples and dioxin parameter samples were located through a combined random and judgmental approach. Indicator and dioxin parameter samples were collected solely along Ciba-Geigy transportation routes (the railway and the old roadway) and around Ciba-Geigy production facilities, while the HSL parameter samples were collected at all the remaining investigation areas. Figures 5-2 through 5-6 provide maps of the major investigation areas sampled, and of soil sample locations within each investigation area. Appendix A-1 provides the laboratory analytical data and descriptions of each sample location. Table 5-1 provides the number of random and judgmental samples taken in each investigation area.

All distances and directions for the 57 randomly located samples collected for the analyses of HSL parameters were designated prior to field sampling activities. Along the railway, five-hundred-foot intervals were measured, by pacing, starting at the boundary fence. Along the old roadway, four-hundred-foot intervals were measured, by a measuring tape, starting from a control point. In both cases a sample was taken within each interval. Judgmental samples were located relative to the closest available control point, usually a well or building. Distances were determined by taping or pacing. Directions were determined from a Brunton compass corrected for magnetic north to provide true bearings.

Judgmental samples were collected in all investigation areas, except the Control Area. Judgmental samples were located on the basis of a field reconnaissance determining where contamiantion would most likley be high concentrations. Random samples were taken in five of the eleven potentially contamianted areas. The decision to randomly sample only these five areas was based on physical size. The area which were chosen cover larger areas than those which were not. The smaller areas were sufficiently characterized by the judgmental samples while the larger areas required random samples to be characterized.



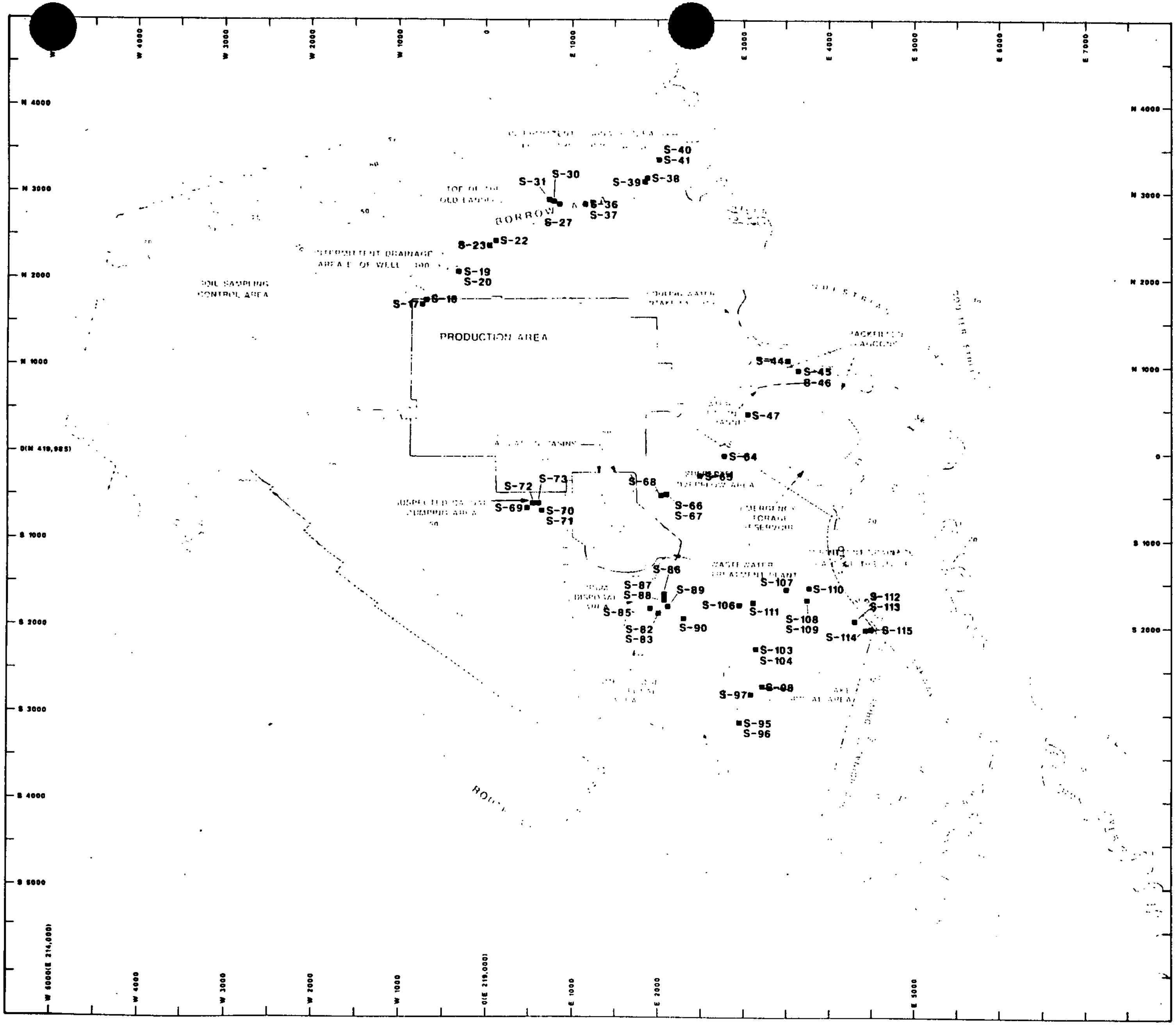
RANDOM SURFACE SOIL SAMPLING LOCATIONS

LEGEND :

- RAILROAD SPUR
- SURVEYED BOUNDARY
- BOUNDARY FENCE
- BOUNDARY ROAD
- —50— CONTOUR LINE
- --45-- SUPPLEMENTAL CONTOUR LINE

FIGURE 5-2

NUS CORPORATION



JUDGMENTAL SURFACE SOIL SAMPLING LOCATIONS

LEGEND :

- —+—+— RAILROAD SPUR
- —··—·— SURVEYED BOUNDARY
- —·—·— BOUNDARY FENCE
- - - - - - BOUNDARY ROAD
- ~50~ CONTOUR LINE
- - -15- - SUPPLEMENTAL CONTOUR LINE

FIGURE 5-3

NUS CORPORATION
A Halliburton Company

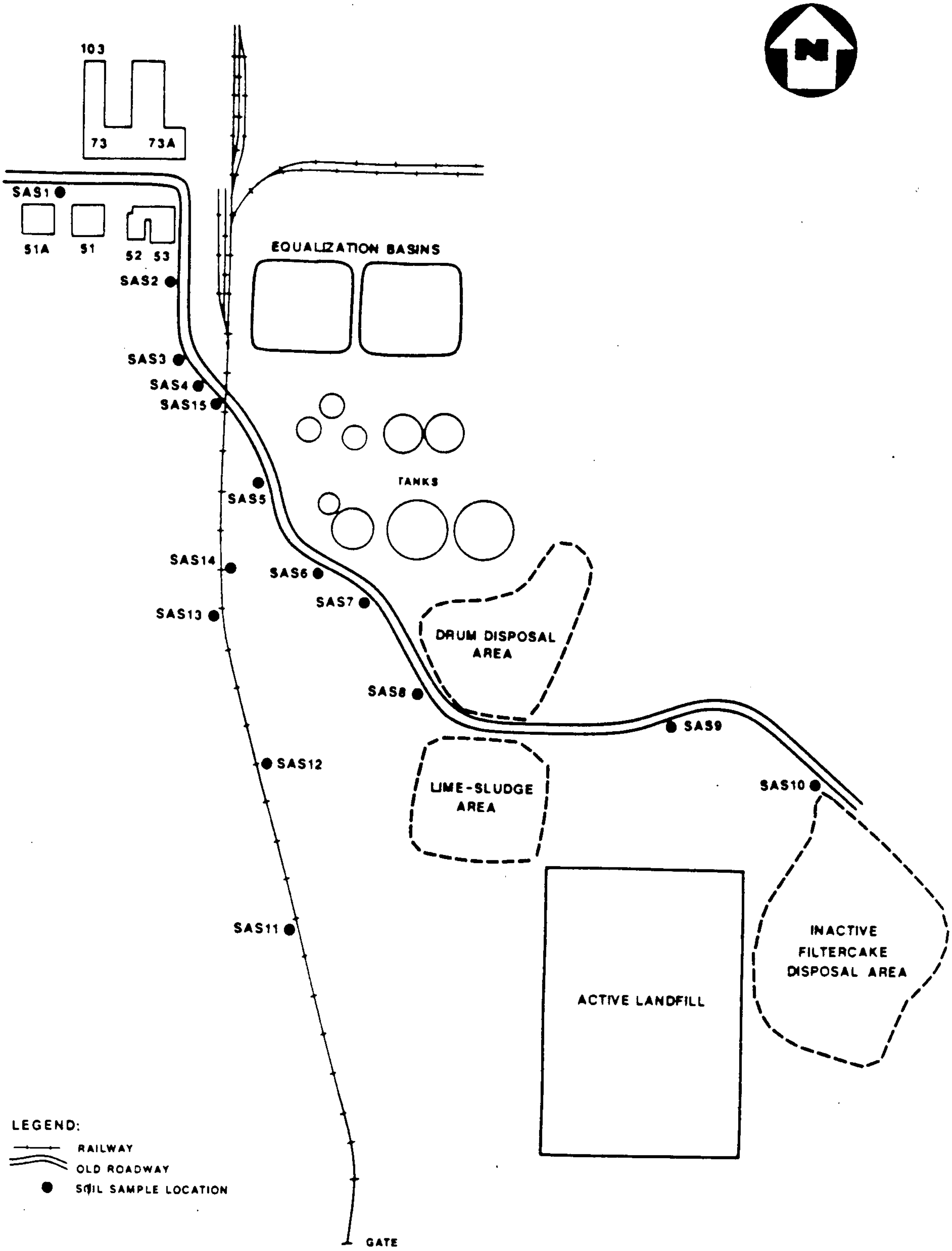


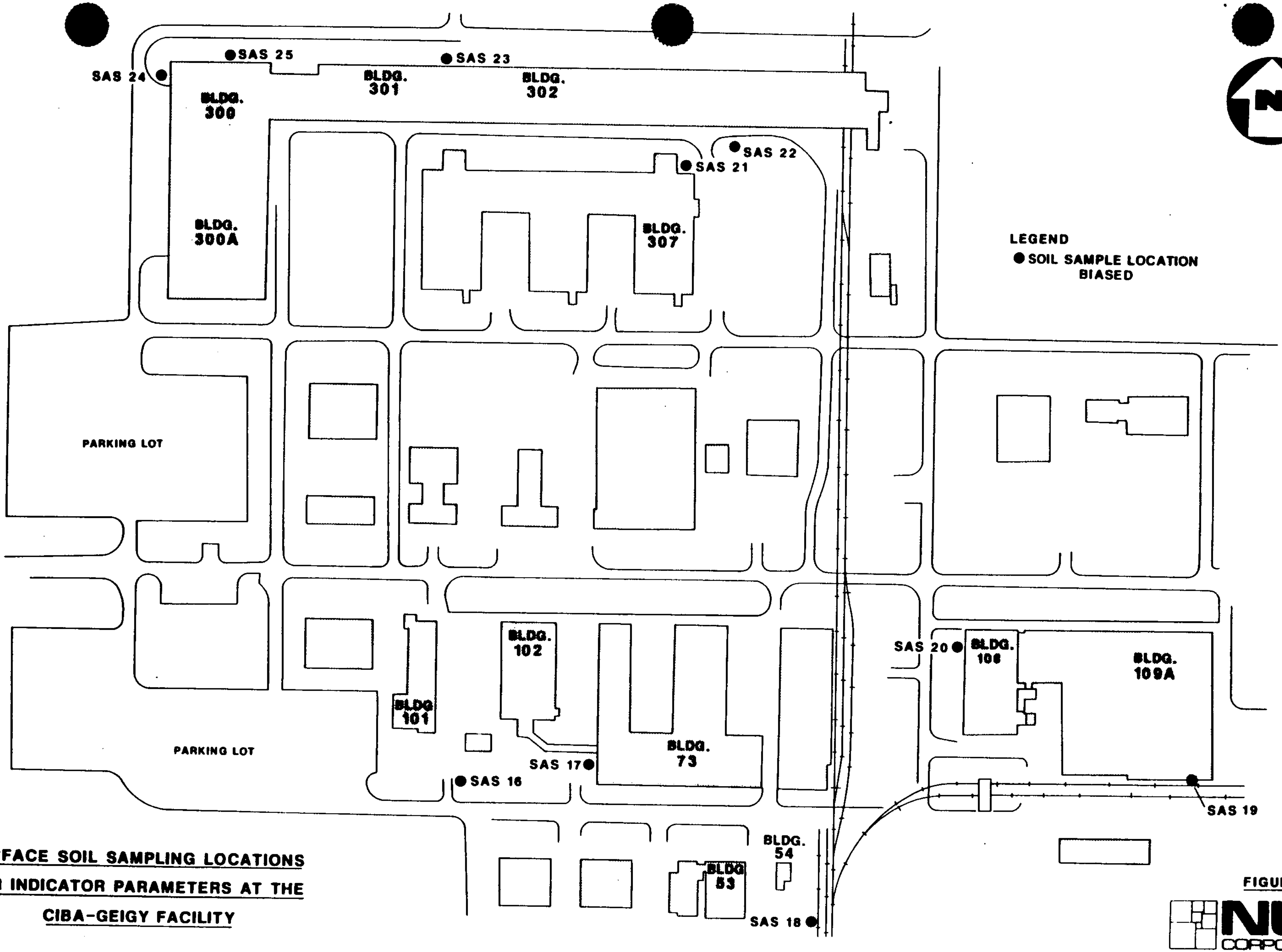
FIGURE 5.4

SURFACE SOIL SAMPLING LOCATIONS

FOR INDICATOR PARAMETERS ALONG TRANSPORTATION ROUTES

NUS CORPORATION

SCALE: 1" = 360'



LEGEND

● SOIL SAMPLE LOCATION BIASED

SURFACE SOIL SAMPLING LOCATIONS FOR INDICATOR PARAMETERS AT THE CIBA-GEIGY FACILITY

SCALE: 1"= 200'

FIGURE 5-5

NUS CORPORATION
A Halliburton Company

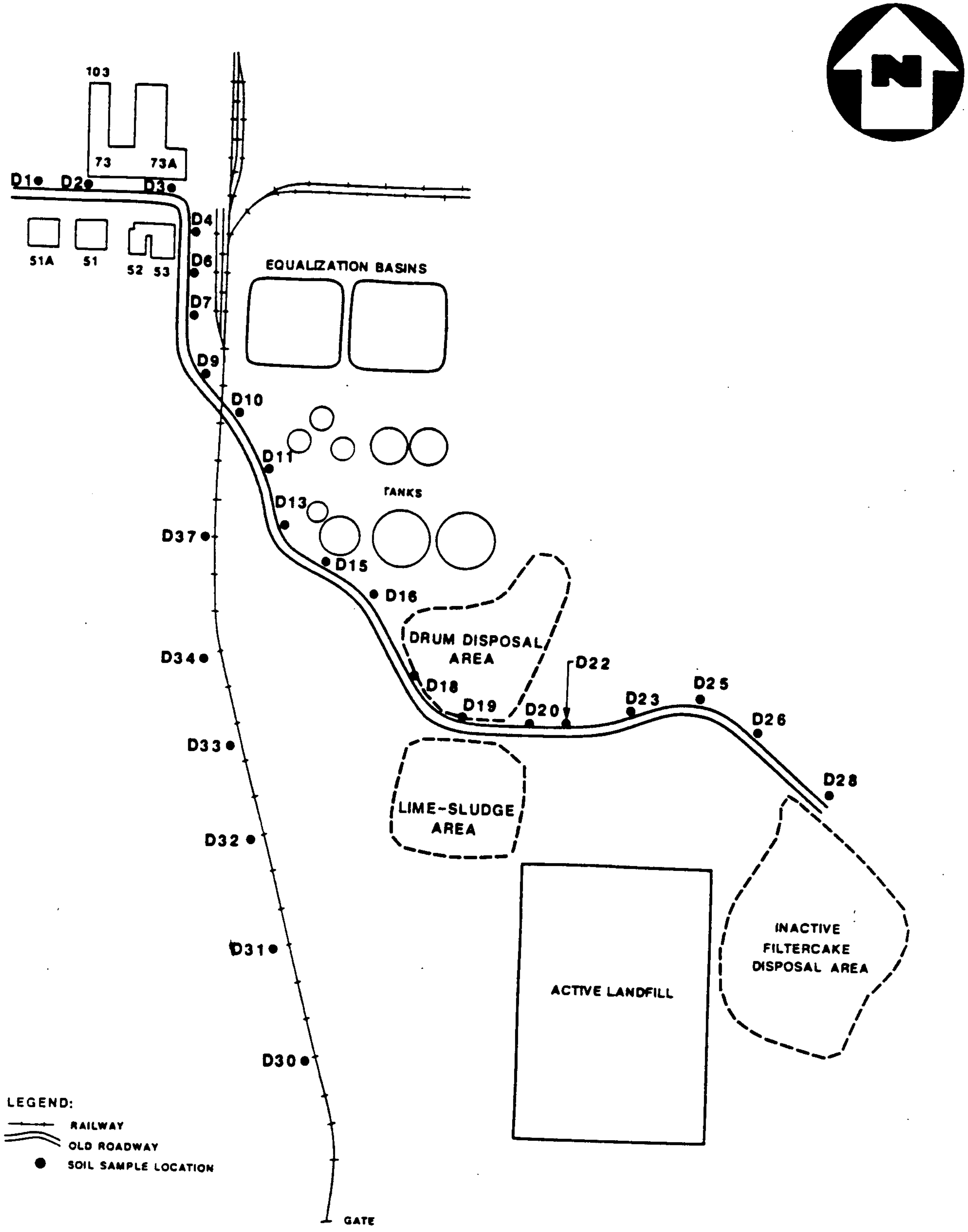


FIGURE 5-6

SURFACE SOIL SAMPLING LOCATIONS FOR DIOXIN ALONG TRANSPORTATION ROUTES

SCALE 1"= 360'

NUS CORPORATION

TABLE 5-1
NUMBER OF RANDOM AND JUDGMENTAL SAMPLES TAKEN IN EACH INVESTIGATION AREA

Investigation Area	Number of Random Samples	Number of Judgmental Samples
Backfilled Lagoons Area	8	4
Borrow Area	9	11
Drum Disposal Area and Lime-Sludge Area	8	8
Control Area	16	0
Production Area	0	21
Filtercake Area	8	6
Intermittent Drainage Area East of the Wastewater Treatment Plant	0	10
Intermittent Drainage Area East of Well No. 400	0	4
Suspected Casual Dumping Area	0	5
Suspected Overflow Area	8	5
Transportation Route (Old Roadway)	0	31
Transportation Route (Railway)	0	10

5.3.2 Results of Random Sampling

Table 5-2 presents the results of the Wilcoxon-Mann-Whitney (W-M-W) Test of significance for HSL parameters at random locations in the five soil investigation areas. Random soil sampling efforts were undertaken to determine whether any of the five investigation areas taken as whole units have a higher true average contaminant level than the Control Area. Several soil samples contained HSL parameters at concentrations too low for laboratory quantification. In order to perform the W-M-W rank sum test, these parameters were assigned a value of zero. For most of the comparisons, the W-M-W test required an HSL parameter to be present in at least three of the six soil samples collected in an investigation area in order to conclude, at a 90 percent probability level, that the parameter in that area has a true average signficantly greater than the corresponding average in the Control Area. For example, several HSL parameters were present in either one or two samples in the Filtercake Disposal Area and the Chemical Landfills Area, but the overall concentrations were not judged to be significantly different from those in the Control Area.

In all five areas sampled randomly, inorganics were found to have greater true average contaminant concentrations than in the Control Area. In addition, these concentrations exceed those found in natural soils (ATSDR, 1986). It is therefore concluded that all five areas are contaminated with inorganics.

Organic results; however, indicate that only the Filtercake Area had a true average concentration greater than that of the Control Area. The Filtercake Area has total VOA concentrations exceeding 1 ppm and total Base/Neutral concentrations exceeding 10 ppm. Therefore, it is concluded that the Filtercake Area as a whole unit is contaminated with organic compounds.

5.3.3 Results of Judgmental Sampling

This section presents the results of the judgmental soil samples (Appendix A-1). For each area, the contaminants or class of contaminants found will be stated. A comparison with concentrations from the Control Area will then be made. The

TABLE 5-2
RESULTS OF WILCOXON-MANN-WHITNEY TEST FOR RANDOMLY LOCATED SAMPLES TESTED FOR HSL PARAMETERS IN SURFACE SOILS AT THE CIBA-GEIGY SITE

HSL PARAMETER	INVESTIGATION AREAS				
	Borrow Area	Backfilled Lagoons Area	Suspected E. Overflow Area	Drum Disposal Area and Lime-Sludge Area	Filtercake Disposal Area
Aluminum	*	*	*	*	*
Chromium	*	*	*	*	*
Copper					*
Manganese	*	*	*	*	
Mercury		*	*		*
Zinc		*	*		*
Di-n-butyl phthalate					*
Anthracene					*
1,2,4-Trichlorobenzene					*
2-Butanone					*
Toluene					*

*Denotes a 90 percent probability of a greater median soil concentration than in the control area.

Control Area is used because it provides the most local background contaminant concentrations. Table 5-3 presents pesticide concentrations in the Control Area and the other areas. Finally, any migration evidence or potential will be discussed.

Backfilled Lagoons Area

Aniline, heptachlor epoxide, and several inorganics were detected in the Backfilled Lagoons Area. The maximum detected concentration of aniline was 1.8 ppm. Aniline was not detected in the Control Area. The maximum detected concentration of heptachlor epoxide was 0.34 ppm. Heptachlor epoxide was not detected in the Control Area. Three inorganics -- chromium, magnesium, and mercury -- had concentrations above the Control Area and above those found in natural soils (ATSDR, 1986). The sampling locations that contained the highest concentrations of pesticides and inorganics are on the east side of the lagoons and within 1000 feet of the Toms River. No evidence presently exists to suggest that surface borne migration is presently occurring; however, migration of surface sediment is possible. Due to the elevated concentrations noted above, the Backfilled Lagoons Area requires consideration for remediation.

Borrow Area

Three Base/Neutrals, three inorganics, bis(2-ethylhexyl) phthalate, 4,4'-DDE, and 4,4'-DDT were detected in the Borrow Area. The highest total concentration of Base/Neutrals in a sample was 1.84 ppm. This is significantly above what was found in the Control Area. Copper, mercury, and selenium are the inorganics that had concentrations above the Control Area and above those found in natural soils. Soil samples S28, S29, S32, S33, S34, and S35 were taken from the intermittent drainage path downgradient of the contaminated soils. These downgradient samples had detectable levels of copper and mercury that were below the quantitation detection limits. Because copper and mercury are found in natural, uncontaminated soils, and the levels detected downgradient show no pattern and are within natural limits, it is concluded that the copper and mercury are not migrating through the intermittent drainage ditch. Concentrations below 1.0 ppm of bis(2-ethylhexyl) phthalate were detected in three samples. In a replicate pair,

TABLE 5-3

PESTICIDES IN SURFACE SOIL SAMPLING

Area	Sample Number	Chlordane	4,4'-DDE	4,4'-DDT	Dieldrin	Endosulfan II	Heptachlor epoxide
Backfilled Lagoons Area	S45						0.340
	S46R						0.300
Borrow Area	S27		0.010	0.037			
	S30			0.160			
	S22		0.0097	0.014			
	S23		0.0052	0.015			
Drum Disposal Area/ Lime Sludge Area	S80		0.0048*		0.006*		
Control Area	S1			0.013*			
	S2			0.0078*			
	S3			0.0075*			
	S4R			0.013*			
	S5			0.021*			
	S6			0.014*			
	S7			0.011*			
Production Area	SAS16	2.8					
	SAS17	3.1					
	SAS22	0.220					
	SAS24		0.020	0.120			
	SAS25			0.015			
Filtercake Disposal Area	S91	0.080*				0.170*	
	S92R					0.110*	
	S93					0.130*	
	S97					9.0	
	S98					7.8	

NOTE: All concentrations are in ppm
* - sample is a randomly located sample.

TABLE 5-3 (CONT'D)
PESTICIDES IN SURFACE SOIL SAMPLING

Area	Sample Number	Chlordane	4,4'-DDE	4,4'-DDT	Dieldrin	Endosulfan II	Heptachlor epoxide
Intermittent Drainage Area East of the Wastewater Treatment Plant							
Intermittent Drainage Area East of Well No. 400	S19			0.180			0.022
	S20R			0.300			0.033
Suspected Casual Dumping Area	S70		0.0064	0.017			
	S71R		0.0065	0.013			
	SS72			0.015			
	S73			0.011			
Suspected East Overflow Area	S61			0.0068*			
	S62R			0.014*			
Transportation Route - Old Roadway	SAS1	0.140					
	SAS2	0.120					
Transportation Route - Railway							

NOTE: All concentrations are in ppm
* - sample is a randomly located sample.

one of the samples showed a concentration of 2.8 ppm, while the other sample in the replicate pair detected bis(2-ethylhexyl) phthalate only below the quantitation limit. Since bis(2-ethylhexyl) phthalate is a common laboratory contaminant, the discrepancy between the replicate pair may be explained by laboratory contamination. The concentrations of 4,4'-DDE and 4,4'-DDT found in the Borrow Area are above those found in the Control Area. However, the concentrations of 4,4'-DDT found in the Borrow Area are below those concentrations found in natural soils (World Health, 1979). Remediation of the Borrow Area should be considered because inorganics, Base/Neutrals, and pesticides occur at concentrations above background.

Drums Disposal Area and Lime Sludge Area

Volatile organics, Base/Neutrals, mercury, dieldrin, and 4,4'-DDE were detected in the Drum Disposal Area and the Lime Sludge Area. 2-Butanone, 1,1,1-trichloroethane, and styrene were the volatile organics detected. Because these soil samples were taken between 0 and 4 inches a depth at which volatile organics from a surface source would be expected to have already volatilized, a subsurface source of volatile organic contamination is suggested. Phenanthrene, fluoranthene, bis(2-ethylhexyl) phthalate, benzo(b) fluoranthene, and benzo(k) fluoranthene, were detected at concentrations exceeding those found in the Control Area. Mercury is the only inorganic which was detected at concentrations exceeding both the Control Area and natural soil levels. Pesticides 4,4'-DDE and dieldrin were both found in sample S80 at concentrations of 0.0048 ppm and 0.006 ppm, respectively, which exceed the concentrations found in the Control Area. Neither pesticide was detected in the surrounding samples. Due to the detection of volatile organics, mercury, and Base/Neutrals, the Drum Disposal Area and Lime Sludge Area require consideration during remediation. Of special concern is the possible subsurface source for the volatile organics contamination; further borings and subsurface sampling will be necessary to completely determine the extent of contamination.

Production Area

PCBs, inorganics, chlordane, 4,4'-DDE, and 4,4'-DDT were detected in the Production Area. Aroclor-1254, a PCB, was detected in sample SAS23. Dioxin testing was performed, but 2,3,7,8-TCDD was not detected in any of the samples. Copper and mercury were detected at concentrations exceeding those in the Control Area and in natural soils. The pesticides chlordane, 4,4'-DDE, and 4,4'-DDT were all detected above background levels. Chlordane is of greatest concern because the concentrations were as high as 3.1 ppm. As a result of the changing drainage patterns within the production facility, it is difficult to determine whether there is migration of the contaminants. Due to the elevated levels of inorganics and pesticides, the areas around samples SAS16, SAS17, SAS19, and SAS22 through SAS24 in the Production Area should be considered during remediation.

Filtercake Area

Volatile organics, Base/Neutrals, inorganics, bis(2-ethylhexyl) phthalate, chlordane, PCBs, and endosulfan II were detected in the Filtercake Area. The volatile organics tetrachloroethene, toluene, and chlorobenzene were found in the soils at high levels. Because these soil samples are taken at a depth of 0 to 4 inches where volatile organics from surface sources would be expected to have already volatilized, these concentrations indicate a subsurface source for volatile organics. In addition, these particular volatile organics are also found in the groundwater. Seven Base/Neutrals are found in the soil samples at concentrations above background. Chromium, copper, magnesium, and mercury all had concentrations that exceeded the Control Area and natural soil concentrations. One sample, S91, had a measurable concentration of bis(2-ethylhexyl) phthalate. The same sample also had the only measurable concentration of chlordane and PCBs. Further testing in the area of S91 is required because its replicate sample, S92, did not contain these contaminants. Endosulfan II was detected at levels that exceed background values. Due to the volatile organics, Base/Neutrals, and inorganics detected, the Filtercake Disposal Area requires consideration during remediation.

Intermittent Drainage Area East of the Wastewater Treatment Plant

Detectable levels of inorganics and 4,4'-DDE were found in the Intermittent Drainage Area East of the Wastewater Treatment Plant (WWTP). Copper and mercury were detected at concentrations exceeding those in the Control Area and in natural soils. Mercury concentration was greatest in sample S107 (65 ppm) with lower levels in samples S110, S112, S114, and S115 (16 ppm, 1.1 ppm, 0.78 ppm, and 0.2 ppm, respectively). These samples decrease in concentration with increased distance downgradient from S107. Therefore, it is concluded that mercury is being transported by sediment, downgradient towards the Toms River. 4,4'-DDE was detected at a concentration of 0.001 ppm. The Control Area had no 4,4'-DDE above the detection limit. Due to concern over the inorganic contamination, the area around S107 needs to be considered for remediation.

Intermittent Drainage Area East of Well No. 400

Base/Neutrals, bis(2-ethylhexyl) phthalate, heptachlor epoxide, and 4,4'-DDT were detected in the Intermittent Drainage Area East of Well No. 400. The detected values of Base/Neutrals were in the range of 23 ppm to 77 ppm, which are above the Control Area concentrations. Bis(2-ethylhexyl) phthalate and the two pesticides, heptachlor epoxide and 4,4'-DDT, were also detected at values exceeding those of the Control Area. Sampling downgradient in the Borrow Area does not yield any evidence to support migration of these contaminants. However, further study to determine the area and depth of contamination is required.

Suspected Casual Dumping Area

Anthracene, 4,4'-DDE, and 4,4'-DDT were detected in the Suspected Casual Dumping Area. The concentration of anthracene was 12,000 ppm. It should be noted that this high concentration would tend to mask detection of other Base/Neutrals at concentrations in the lower ppm range. Therefore, it is not known whether other Base/Neutral contaminants are present in that sample. 4,4'-DDE was detected at levels which exceed those found in the Control Area. 4,4'-DDT was also found, but the concentrations were below those found in the Control

Area. Sampling to determine the extent of anthracene contamination is necessary. Samples in locations which would reveal migration were not taken; therefore, no determination of migration is possible.

Suspected East Overflow Area

4,4'-DDT and nitrobenzene were the only two noninorganic substances detected above the quantitation limits in the Suspected East Overflow Area. The concentration of 4,4'-DDT was below those found in the Control Area, and therefore, is considered to be background. Nitrobenzene; however, was detected above the concentrations found in the Control Area. Of the inorganics, the detected levels did not exceed those found in natural soils. However, mercury was detected at levels above those found in the Control Area. Because mercury has been found in many other areas on the Ciba-Geigy Site and its concentration is above those in the Control Area, these concentrations are of concern. These mercury levels justify further subsurface sampling to determine if the Suspected East Overflow Area is a source of contamination.

Transportation Route - Old Roadway

PCBs, chlordane, and inorganics were detected along the Transportation Route - Old Roadway. The PCB and chlordane concentrations detected were above those found in the Control Area. Copper and mercury are the only two inorganics which were detected at concentrations above those of the Control Area and above those found in natural soils. Concentrations of mercury were highest along the roadway near the tanks (Figure 5-4) and decreased to lower concentrations with distance. The only exception to this is the sample taken near the Filtercake Area. The pattern of contamination distribution suggests that the source of contamination is near the storage tanks and the contamination has been spread along the old roadway. Dioxin samples were also collected along the old roadway, but results showed no detectable 2,3,7,8-tetrachlorodibenzo-p-dioxin. Due to the PCB, pesticides, and inorganic contamination, the old roadway should be considered for remediation.

Transportation Route - Railway

Only inorganic contaminants were detected in the Transportation Route - Railway. The inorganic concentrations were all below those found in the Control Area and those found in natural soils. Dioxin samples were also taken. Results showed no detectable 2,3,7,8-tetrachlorodibenzo-p-dioxin. Organic HSL parameters were not analyzed for in these samples. Therefore, no conclusion may be made concerning organic contamination. Due to the lack of contamination, this area is considered acceptably clean; however organic testing was not completed and further study would be necessary if evidence appeared to suggest organic contamination.

Of the areas mentioned, only the Railway is considered to be uncontaminated and not in need of remediation. The other areas require consideration for remediation. It is important to note that the whole area may not need remediation but only those localized areas where contaminant concentrations are unacceptable. Particular attention must be paid to possible migratory routes.

5.3.4 Sampling Precision Results

Sampling precision for the soil investigation is presented in Table 5-4. Each value in the table represents the precision resulting from one replicate pair of samples. Precision values are not given whenever an HSL parameter is undetected in either a sample or a sample replicate. Twenty-seven replicates were collected. Both individual and averaged precision values are given for each HSL parameter and investigation area.

Sampling precision averages by investigation area ranged from 8 to 36 percent. Precision averages by HSL parameter ranged from 2 to 121 percent. The overall sampling precision for the soil investigation was 21 percent. According to Barth and Mason (1984) precision values of less than ± 20 percent (equivalent to 40 percent total precision) are probably unrealistic for a field soil sampling effort. Results of this study are therefore acceptable.

TABLE 5.4 - SOIL SAMPLING PRECISION (PERCENT) AT THE CIBA-GEIGY SITE[a]

INVESTIGATION AREAS

HSL PARAMETER	SUSPECTED CASUAL DUMPING AREA	INTERMITTENT DRAINAGE EAST OF WELL 400	SUSPECTED EAST OVERFLOW AREA	INTERMITTENT DRAINAGE - BORROW AREA	BACKFILLED LAGOONS AREA	CHEMICAL LANDFILLS AREA	FILTERCAKE DISPOSAL AREA	INTERMITTENT DRAINAGE EAST OF WWTP	BORROW AREA	CONTROL AREA	AVERAGE (RANGE) OF PRECISION FOR EACH HSL PARAMETER
2-BUTANONE											
TETRACHLOROETHENE							85				85
ANILINE							115				115
1,2-DICHLOROBENZENE					6						6
1,2,4-TRICHLOROBENZENE							29				29
PHENANTHRENE							121;8				64 (8-121)
ANTHRACENE						87	8				48 (8-87)
DI-n-BUTYLPHTHALATE							44;12				28 (12-44)
FLUORANTHENE							2				2
BUTYLBENZYLPHTHALATE						92					92
BENZO(b)FLUORANTHENE							38				38
HEPTACHLOR EPOXIDE		4									4
4,4'-DDE		40			13						27 (13-40)
ENDOSULFAN II	2										2
4,4'-DDT							43				43
ALUMINUM	27	50	69							54;19	44 (19-69)
ANTIMONY	15	14	0.5; 9; 5	3; 12	9; 2; 8	17; 14; 12; 27	13; 33; 17; 23	11; 14	2; 14; 6	10;5;3;32	13 (0.5-33)
ARSENIC							30				30
CALCIUM			2			24	26				17 (2-26)
CHROMIUM					56		35				46 (35-56)
COPPER		29	16; 10; 33	19	4; 43; 32	105	24; 48; 30; 5	14; 9	0; 21		26 (0-105)
IRON			17		27	34	32; 5; 35; 27				25 (5-35)
LEAD	10	18	6; 4; 0.3	2;9	6; 2; 11	33; 24; 17; 6	24; 18; 13; 23	8; 9	3; 10; 5	18;0.6;3;28	12 (0.3-33)
MAGNESIUM	24		12; 0		0	47; 14	6	8; 54		40;12;14;0	18 (0-54)
MANGANESE					6		24				15 (6-24)
MERCURY	12	30	12; 5; 6	0	5; 9	13	10	9	17; 17		11 (0-30)
CHLOROBENZENE			5; 9		46; 11	46	19; 4; 2	36; 40			22 (2-46)
THALLIUM							196				196
TIN					34		30,35				33 (30-35)
VANADIUM					6		50; 17; 42				29 (6-50)
ZINC		10			17		22; 13; 24; 52				23 (13-52)
AVERAGE (RANGE) OF PRECISION FOR EACH INVESTIGATION AREA	15 (2-27)	24 (4-50)	12 (0-69)	8 (0-19)	16 (0-56)	36 (6-105)	33 (2-196)	19 (8-54)	10 (0-21)	17 (0-54)	21[b]

NOTES:

a - DATA FROM BOTH RANDOM AND JUDGMENTAL LOCATIONS ARE COMBINED

b - TOTAL SAMPLING PRECISION FOR THE ENTIRE SOIL INVESTIGATION, CALCULATED AS THE SUM OF ALL INDIVIDUAL PRECISION VALUES DIVIDED BY THE TOTAL NUMBER OF REPLICATE PAIRS.

The precision associated with mercury concentrations is of particular importance because it is found in most of the contaminated areas. The proper characterization of associated exposure risks requires the correct concentrations to be used. For example, mercury concentrations in the Filtercake Disposal Area were as high as 231 ppm, with a total sampling precision of 19 percent. The precision associated with this concentration is ± 9.5 percent (one-half the total precision) or 231 ± 22 ppm. The appropriate soil mercury concentration for evaluating worst case conditions is thus 253 ppm.

During analysis by the laboratory, some problems were encountered. Exceeded holding times, duplicate analysis differing from original analysis, and insufficient spike recovery are some problems that cause data to fail Quality Assurance and Quality Control (QA/QC). Data that have failed QA/QC is denoted by the entry "E" where the concentration would normally be found in Appendix A-1. When data fails QA/QC the only conclusions that may be made is that the analysis is indeterminate with respect to contaminant concentration and presence. However, in this case, the amount of data that failed QA/QC has not seriously hindered the overall analysis of surface soil contamination.

5.4 Conclusions

Overall sampling precision for the soil investigation was 21 percent, a good result for a field sampling effort. The Control Area at the Ciba-Geigy facility fulfilled all the requirements for establishing a site-specific background level of HSL parameters.

The surface soil results reveal several areas where inorganic contamination is a problem. The inorganics tended to be localized within investigation areas. There is evidence that contaminants are migrating from the contaminated areas. When considering remediation priority, those areas where migration is occurring should be considered more critical than those where migration is not occurring. Also, the fact that the samples were all taken from depths of 0 to 4 inches means that direct contact is a possible exposure route. Due to the large and extensive vegetation cover over the contaminated areas, dust-borne contamination is not considered a potential exposure route. If, however, the vegetation were removed (possible fire or clearing by Ciba-Geigy), dust exposure may become possible. Sediment-, surface-water-, and groundwater-borne contaminants are all possible. Each of these three exposure routes have populations that may be affected.

Organic surface soil contamination is not as widely spread as is the inorganic contamination. 4,4'-DDT is a pesticide which is sometimes found in natural soils and was found in many soil samples from the Ciba-Geigy Site. The Control Area was used as a source for background levels of this pesticide. No other pesticides were detected in the Control Area; however, chlordane, 4,4'-DDE, dieldrin, endosulfan II, and heptachlor epoxide were detected on site (Table 5-3). The concentrations of 4,4'-DDT in the Control Area are consistent with those found in natural soils (World Health Organization, 1979). The Backfilled Lagoons Area, Borrow Area, Drum Disposal Area, Filtercake Area, Intermittent Drainage Area East of Well No. 400, and Suspected Casual Dumping Area contained organic contamination other than pesticides.

Dioxin samples from the Production Area and the Old Roadway were analyzed for 2,3,7,8-tetrachlorodibenzo-p-dioxin. Three of the samples were not accepted due to QA/QC problems, but the remaining 55 samples had no detected 2,3,7,8-tetrachlorodibenzo-p-dioxin.

Additional surface soil sampling and subsurface sampling is required to further define those areas where soil contamination was identified. Inorganic contamination predominated in all areas with the exception of the Filtercake Area where extensive organic contamination was also found. Sources for the inorganic contamination must be identified by subsurface sampling before proper remediation can be accomplished. The valence of mercury and chromium effects both mobility and toxicity of the contamination and therefore future studies should include the determination of specific valence concentrations. Futher subsurface sampling is necessary to isolate the source of organic volatile contamination that was detected in the surface soils. Further sampling is also required around the locations of samples that had elevated contaminant concentrations. This sampling should be spaced to determine the areal extent of contamination to the degree of precision required by remediation processes.

6

6.0 SURFACE WATER AND SEDIMENT INVESTIGATION

The objective of the surface water and sediment investigation was to assess the potential for contaminant migration from the Ciba-Geigy Site. Surface water and sediment samples were collected from the Toms River upstream, adjacent to, and downstream from the Ciba-Geigy Site. Samples collected upstream from the Ciba-Geigy Site established background contaminant levels in the river. Samples from the river adjacent to the Ciba-Geigy Site isolated an area of contaminant loading to the river, with contaminants emanating from the site due to past or present practices at Ciba-Geigy. Samples collected downstream from the Ciba-Geigy Site delineated the extent of contaminant migration through the drainage basin of the Toms River. The investigation of surface water is necessary because past practices of Ciba-Geigy may have directly contaminated the river through effluents. In addition, contaminated groundwater may be discharging into the river.

6.1 Surface Water Description

Quantitative and qualitative environmental data that characterize the surface waters of the Toms River are compiled in the following sections.

6.1.1 Drainage Patterns

The drainage course of the Toms River traverses Ocean County along a 16-mile pathway from the northwest to the southeast (Figure 6-1). The main channel of the Toms River, along with the associated tributaries of the river system, provides drainage to a basin encompassing 190 square miles. Headwaters of the Toms River are located in Millstone Township, Monmouth County, and flow through relatively undeveloped forest and agricultural lands. Four major tributaries contribute to the hydraulic flow in the upper reaches of the river. The Maple Root Branch originates from forested lands at an elevation of 100 feet MSL, and joins the main stem of the Toms River at the 13.4-mile mark. The drainage of Long Brook, located immediately to the south of the Maple Root Branch, flows into the Toms River at

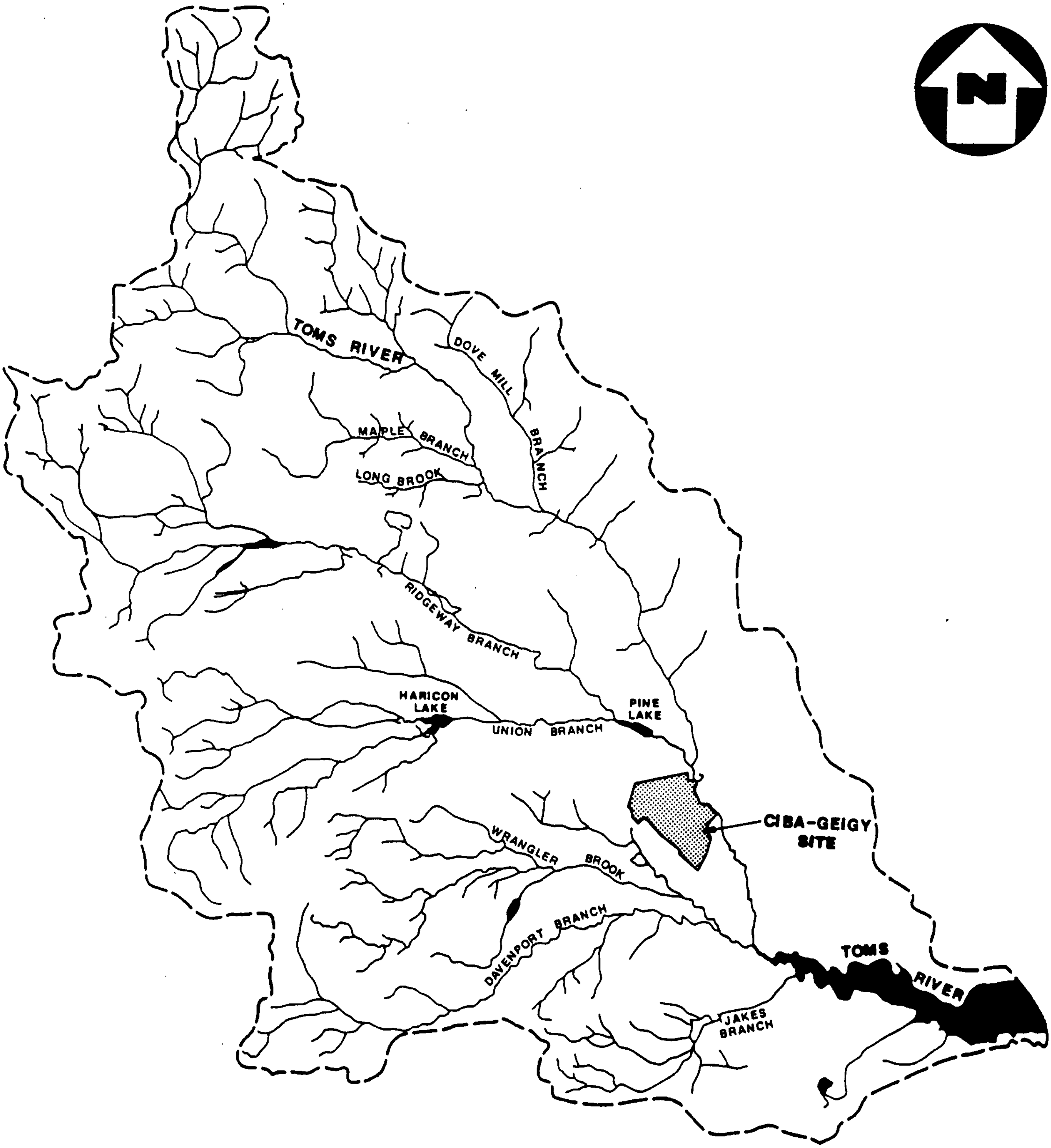


FIGURE 6-1

THE DRAINAGE BASIN OF THE TOMS RIVER, OCEAN COUNTY, NEW JERSEY

SCALE: 1"= 12,672'

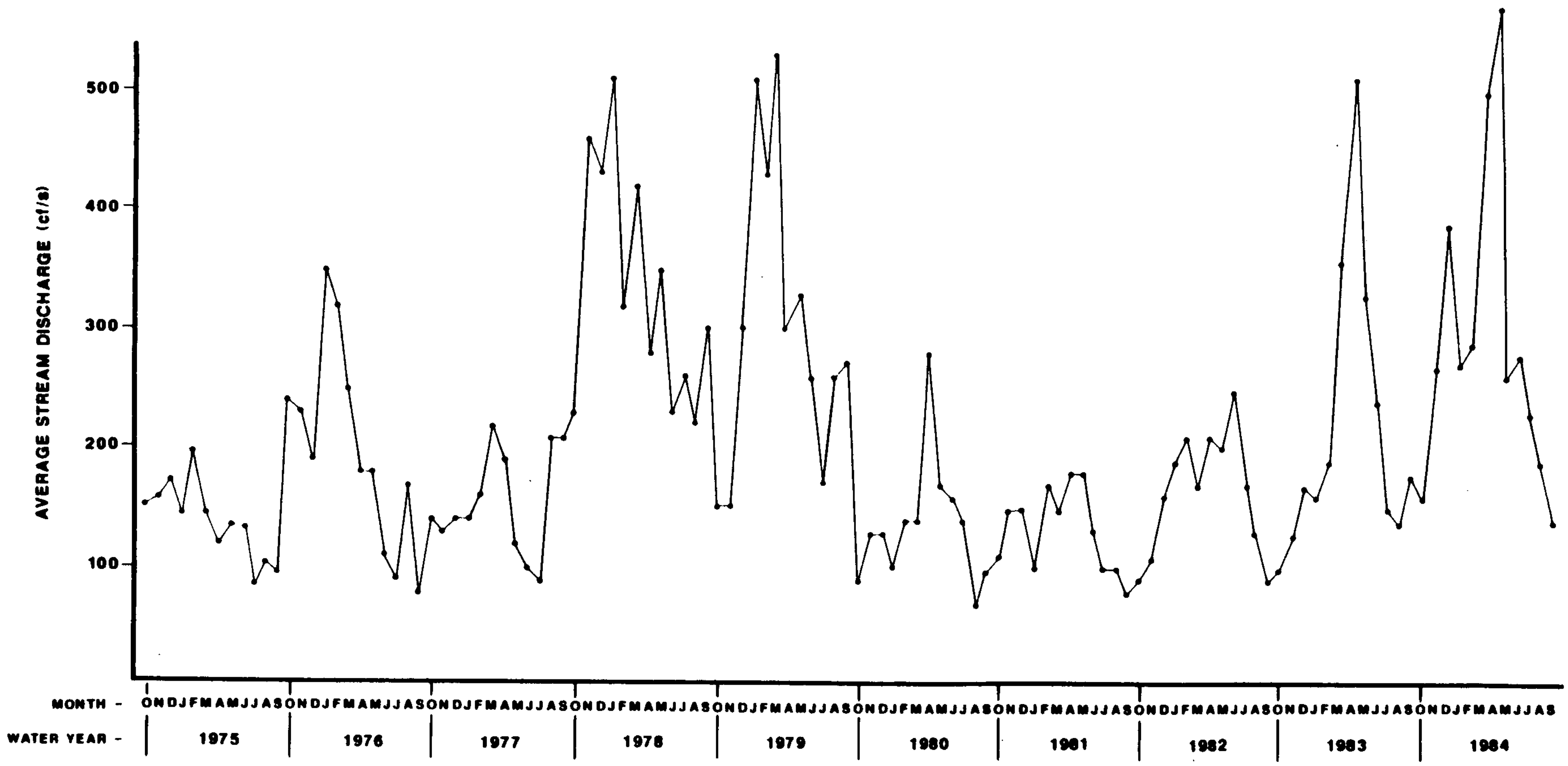
NUS CORPORATION

the 13-mile mark. Dove Mill Branch emanates from cranberry bogs at an elevation of 60 feet MSL to the north of the main stem of the river, and joins the river at mile mark 11.7. Union Branch of the Toms River originates from Haricon Lake at an elevation of 60 feet MSL. At an elevation of 40 feet MSL, the confluence of Union Branch and Ridgeway Branch form Pine Lake. Both tributaries are influenced by surface drainage from the Lakehurst Naval Air Station and from residential development surrounding the town of Lakehurst. Union Branch joins the main channel of the Toms River at the 11-mile mark. Surface waters from all tributaries in the northern drainage basin of the Toms River contribute to the hydraulic flow and water quality at the Ciba-Geigy Site located between the 8.3- and 9.8-mile marks on the river (OCPB, 1978).

6.1.2 Hydraulic Loading

Figure 6-2 depicts the average surface water discharge of the Toms River for the past 10 years as measured by the U.S. Geological Survey (U.S.G.S.). The U.S.G.S. maintains a gage station (No. 01408500) at the Oak Ridge Parkway Bridge, downstream of the Ciba-Geigy cooling water intake and discharge points. This gage station monitors surface water flow from 125 of the 190 square mile drainage of the Toms River. Average stream discharge of the Toms River for the past 57 years at this location is 215 cf/s (140 MGD). 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 (Table 6-1). For New Jersey Water Year 1985, the maximum surface water discharge in the Toms River (339 cf/s) occurred on September 30. Minimum discharge (51 cf/s) was recorded on September 7. Water-discharge data for the 57-year period of record at the Toms River gage station show that maximum stream flow was recorded on September 23, 1938 (2,000 cf/s), while conditions of minimum stream flow occurred in August and September of 1966 (46 cf/s).

Stream flows in the New Jersey Coastal Plain, including the surface water discharge in the Toms River, are derived primarily from groundwater baseflow.



AVERAGE STREAM DISCHARGE (cf/s) IN THE TOMS RIVER AT U.S.G.S. GAGE STATION 01408500 FOR THE NEW JERSEY WATER YEARS 1975 TO 1984

FIGURE 6-2

NUS CORPORATION

TABLE 6-1
AVERAGE STREAM DISCHARGE (cf/s) IN THE TOMS RIVER AT U.S.G.S. GAGE STATION 01408500 FOR THE NEW JERSEY WATER YEARS 1975 TO 1984

Water Year	Average Stream Discharge (cf/s)											
	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.
10/83 to 9/84	163	268	394	270	286	496	573	358	379	330	189	139
10/82 to 9/83	102	132	165	164	185	363	513	330	236	139	127	177
10/81 to 9/82	90	106	159	193	207	168	214	199	239	170	127	94
10/80 to 9/81	111	141	138	104	172	146	182	175	134	104	103	83
10/79 to 9/80	87	127	126	100	138	140	277	170	162	135	67	95
10/78 to 9/79	154	154	297	505	432	524	304	331	261	168	259	270
10/77 to 9/78	228	465	434	506	319	419	282	354	231	257	218	302
10/76 to 9/77	139	129	135	142	163	217	187	119	97	94	205	211
10/75 to 9/76	235	233	189	351	317	239	179	179	109	94	168	84
10/74 to 9/75	152	157	171	142	198	143	120	131	130	83	102	95

Rhodehamel (1970) developed a hydrologic budget for the Pine Barrens based upon the interrelationship of annual precipitation, annual stream runoff, and annual evapotranspiration:

$$P = R + ET$$

where

P = average annual precipitation, as cm (in.) depth over the area = 113 cm (45 in.)

R = average annual stream runoff, measured as cm (in.) depth over the area = 56.5 cm (22.5 in.) and

ET = average annual evapotranspiration, as cm (in.) depth over the area = 56.5 cm (22.5 in.)

This hydrologic budget assumes that there is no groundwater flow to the Atlantic Ocean due to the seaward decrease in aquifer permeability. The New Jersey Coastal Plain, which encompasses all of the Ciba-Geigy Site, is underlain by a series of interconnected aquifers, notably the Cohansey Sand and the Kirkwood Formation at the Ciba-Geigy Site. Groundwater flow to the ocean is blocked to the south and east by an increase in the silt and clay content of the Cohansey Sand and upper Kirkwood which directs groundwater to the surface. Consequently, groundwater baseflow supplies approximately 89 percent of all river water in the New Jersey Coastal Plain (Rhodehamel, 1970). For the Toms River, groundwater baseflow accounts for approximately 70 percent of the stream discharge (Anderson and Appel, 1969).

6.1.3 Surface Water Chemistry

Baseline surface water chemistry in the Toms River is influenced by three factors:

- Chemistry of atmospheric precipitation
- Chemistry of the underlying soils and geologic materials
- Chemical composition of the natural vegetation

The chemistry of atmospheric precipitation significantly influences the hydrogeochemistry of the Pine Barrens region surrounding the Ciba-Geigy Site. Input of soluble and particulate matter to a drainage basin associated with atmospheric precipitation usually does not alter the geochemistry of streams. Surface water chemistry normally is influenced by the chemical constituents of the soils, underlying geology, and the natural vegetation. However, soils of the Pine Barrens are thin and poorly developed, with the quartz sands and gravels of the Cohansey Sand chemically unreactive and highly permeable. Consequently, the chemistry of undisturbed groundwaters and surface waters in the vicinity of the Ciba-Geigy Site is directly influenced by the chemical composition of the precipitation (Kelsey and Kinsman, 1971).

Tables 6-2 and 6-3 summarize the ionic budget and the annual mass input to the surface waters and groundwaters from precipitation over the Pine Barrens region. Sodium (Na^+), chlorine (Cl^-), and magnesium (Mg^{2+}) are present in the precipitation as soluble salts. Further, the mass input of these ions is correlated with the amount of precipitation; the ionic concentration increases as precipitation increases. Na^+ and Cl^- are derived from marine aerosols, whereas all other dissolved ions are derived from continental sources. Calcium (Ca^{2+}), potassium (K^+), nitrate (NO_3^-), and phosphate (PO_4^{3-}) enter the surface waters as dry fallout, derived principally from soil dust. On the average, 15 metric tons $km^{-2}yr^{-1}$ of these ions are deposited on the Pine Barrens with input to the surface waters averaging 11 metric tons $km^{-2}yr^{-1}$ (Means et al., 1981).

Rainfall in the Pine Barrens is acidic, with a pH of approximately 4.4. Abundant sulfate (SO_4^{2-}) in the atmosphere, derived from sulfur dioxide (SO_2) by-products from the combustion of fossil fuels, is balanced by H^+, which gives rise to the acidic precipitation in the Pine Barrens and throughout the northeast (Cogbill and Likens, 1974). Acidic precipitation directly contributes to the low pH of the surface waters of the Toms River. Median pH in the river for the past 20 years was 5.0.

Mineral deposits in the underlying strata of the Toms River drainage basin provide the source for input of metals to the surface waters of the river. Iron and trace metals present in the surface waters are derived from Tertiary and late Cretaceous

TABLE 6-2
THE IONIC BUDGET AND THE ANNUAL MASS INPUT OF CHEMICAL COMPONENTS TO THE SURFACE WATERS AND GROUNDWATERS FROM PINE BARRENS PRECIPITATION

IONIC BUDGET FOR PINE BARRENS PRECIPITATION

Cations

Na^+	=	1.39 mg L^{-1}/23 g equivalent^{-1}	=	$6.04 \pm 0.06 \times 10^{-2}$ meq L^{-1}
K^+	=	0.32/39	=	$0.82 \pm 0.02 \times 10^{-2}$ meq L^{-1}
Mg^{2+}	=	0.23/12	=	$1.92 \pm 0.02 \times 10^{-2}$ meq L^{-1}
Ca^{2+}	=	1.10/20	=	$5.50 \pm 0.05 \times 10^{-2}$ meq L^{-1}
H^+	=	$10^{-4.41}$	=	$3.89 \pm 0.80 \times 10^{-2}$ meq L^{-1}
Total Cations			=	$18.17 \pm 0.95 \times 10^{-2}$ meq L^{-1}

Anions

Cl^-	=	2.82 mg L^{-1}/35.5 g equivalent^{-1}	=	$7.94 \pm 0.08 \times 10^{-2}$ meq L^{-1}
SO_4^{2-}	=	5.09/48	=	$10.60 \pm 0.50 \times 10^{-2}$ meq L^{-1}
NO_3^-	=	0.39/62	=	$0.63 \pm 0.04 \times 10^{-2}$ meq L^{-1}
PO_4^{3-}	=	0.074/79	=	$0.01 \pm 0.001 \times 10^{-2}$ meq L^{-1}
Total Anions			=	$19.18 \pm 0.62 \times 10^{-2}$ meq L^{-1}

ANNUAL MASS INPUT OF CHEMICAL COMPONENTS FROM PINE BARRENS PRECIPITATION

Cations

Na^+	=	1.85 ± 0.13 metric tons $km^{-2}yr^{-1}$	(4.54 tons mi^{-2} yr^{-1})
K^+	=	0.42 ± 0.04 metric tons $km^{-2}yr^{-1}$	(1.03 tons mi^{-2} yr^{-1})
Mg^{2+}	=	0.31 ± 0.02 metric tons $km^{-2}yr^{-1}$	(0.76 tons mi^{-2} yr^{-1})
Ca^{2+}	=	1.46 ± 0.01 metric tons $km^{-2}yr^{-1}$	(4.58 tons mi^{-2} yr^{-1})
H^+	=	0.052 ± 0.004 metric tons $km^{-2}yr^{-1}$	(0.15 tons mi^{-2} yr^{-1})

Anions

Ci^-	=	3.73 ± 0.26 metric tons $km^{-2}yr^{-1}$	(9.14 tons mi^{-2} yr^{-1})
SO_4^{2-}	=	6.72 ± 0.70 metric tons $km^{-2}yr^{-1}$	(16.47 tons mi^{-2} yr^{-1})
NO_3^-	=	0.52 ± 0.03 metric tons $km^{-2}yr^{-1}$	(1.28 tons mi^{-2} yr^{-1})
PO_4^{3-}	=	0.074 ± 0.001 metric tons $km^{-2}yr^{-1}$	(0.02 tons mi^{-2} yr^{-1})
Total	=	15.14 ± 1.19 metric tons $km^{-2}yr^{-2}$	(36.97 tons mi^{-2} yr^{-1})

*After Means, et al., 1981 from the 1971-72 average of 132 ± 8.0 cm of precipitation.

TABLE 6-3
MASS BALANCES OF THE CHEMICAL COMPONENTS IN PRECIPITATION INPUT VERSUS RIVER OUTPUT FOR THE TOMS RIVER

DATA BASED UPON THE AVERAGE GEOCHEMISTRY OF MAJOR PINE BARRENS RIVER SYSTEMS*

Species	Precipitation Input metric tons km^{-2}yr^{-1}	(tons mi^{-2}yr^{-1})	Output in River metric tons km^{-2}yr^{-1}	(tons mi^{-2}yr^{-1})
Na^+	1.85 ± 0.13	(4.54)	1.99 ± 0.15	(4.88)
K^+	0.42 ± 0.04	(1.03)	0.49 ± 0.04	(1.20)
Mg^{2+}	0.31 ± 0.02	(0.76)	0.44 ± 0.03	(1.08)
Ca^{2+}	1.46 ± 0.01	(3.58)	0.81 ± 0.04	(1.98)
H^+	0.052 ± 0.004	(0.15)	0.042 ± 0.007	(0.10)
Cl^-	3.73 ± 0.26	(9.14)	3.63 ± 0.30	(8.89)
SO_4^{2-}	6.72 ± 0.70	(16.47)	4.74 ± 0.31	(11.61)
NO_3^-	0.52 ± 0.03	(1.28)	---	---
PO_4^{3-}	0.074 ± 0.001	(0.18)	0.028 ± 0.002	(0.068)
Total	15.14 ± 1.19	(35.85)	11.441 ± 0.89	(29.81)

* Mass balances computed by Means et al., 1981.

--- Missing Data

glauconites and glauconitic clays found in the upper Cohansey and Kirkwood Formations. Trace metals in the surface waters of the Pine Barrens follow their order of abundance in glauconite, with the abundance of metals in the surface water decreasing in the following order: Fe, Al, Zn, Mn, Cu, Pb, and Cd. Ferrous iron (Fe^{2+}) is the dominant species at pH less than 5. At higher pH (5.0-5.5) ferric species $Fe(OH)^{2+}$ and $Fe(OH)_2^+$ increase in concentration. Aluminum present in the surface waters at pH 4.3 to 5.4 consists of hydroxyl species such as $Al(OH)^{2+}$, $Al(OH)_2^+$, and $Al(OH)_3$. Zinc is found in the surface waters both in solution and as a colloidal form associated with stream particulate matter. Lead is present in solution and as a colloid, adsorbed to organic-rich iron oxides and hydroxides. Manganese, copper, and cadmium are common at trace concentrations in the surface waters (Means et al., 1981).

Vegetation common to the drainage basin of the Toms River also influences the water quality of the river. The tea color of the waters of the Toms River is caused by the presence of dissolved iron, and humic and fulvic acids. Humic acids in the surface waters originate from the leaching of organic matter of soils and swamplands in an acidic, reducing environment. Soil and swamp organics are ultimately derived from pitch pine (Pinus rigida), Atlantic white cedar (Chamaecyparis thyoides), and several species of sphagnum moss, the dominant vegetation types in the Pine Barrens (Kelsey and Kinsman, 1971). Humic acids contain high phenolic hydroxy and carbonic acid concentrations which readily complex with metals. In an acidic environment, humic acids leach metals from the surface soils, thereby increasing the dissolved metal concentration of the surface waters.

6.1.4 Surface Water Quality

Historical data provide a perspective on changes in chemical parameters which are reflected in the present water quality of the Toms River. Water quality data have been compiled for the past 22 years by the U.S.G.S. at the Oak Ridge Parkway Bridge gage station (No. 01408500), downstream from the Ciba-Geigy cooling water intake and discharge points. Tables 6-4 and 6-5 summarize the baseline chemical composition of the surface waters of the Toms River for New Jersey Water Years 1964 to 1984 (U.S.G.S. Water-Data: NJ-64-1 to NJ-84-1). Blank spaces represent missing data in the U.S.G.S. data base for these years.

TABLE 6-4
THE RANGE OF BASELINE CHEMICAL PARAMETERS FOUND IN THE TOMS RIVER AT U.S.G.S. GAGE STATION 01408500 FOR NEW JERSEY WATER YEARS 1964 TO 1984

Water Year	pH	Dissolved Oxygen (mg/L)	Biochemical Oxygen Demand (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)
10/83 to 9/84	4.4-5.6	8.0-10.8	0.4-1.9	0.71-1.18	0.01-0.07
10/82 to 9/83	4.2-4.9	7.3-11.6	0.8-2.2	0.66-1.00	0.01-0.19
10/81 to 9/82	3.7-5.1	7.8-16.0	0.7-3.0	0.72-1.08	0.02-0.06
10/80 to 9/81	4.1-6.2	8.0-12.4	0.6-2.7	0.36-1.10	0.01-0.06
10/79 to 9/80	4.1-6.1	7.9-12.4	---	0.51-1.00	0.01-0.09
10/78 to 9/79	4.0-6.1	7.9-13.0	0.5-2.4	0.51-0.91	0.02-0.08
10/77 to 9/78	4.0-4.9	7.2-13.8	0.5-2.6	0.53-1.10	0.01-0.07
10/76 to 9/77	4.4-6.2	7.3-15.0	0.6-2.7	0.70-1.40	0.02-0.09
10/75 to 9/76	4.1-6.4	8.1-13.0	0.4-2.3	0.48-1.80	0.03-0.09
10/74 to 9/75	3.9-6.4	6.7-12.4	0.7-8.0	0.33-1.10	0.02-0.09
10/73 to 9/74	4.2-6.1	7.9-12.3	0.7-1.6	0.58-0.78	0.01-0.06
10/72 to 9/73	3.9-7.2	7.6-13.0	0.7-1.6	0.81-1.10	0.01-0.08
10/71 to 9/72	3.4-6.7	5.8-12.7	---	0.24-1.87	0.03-0.11
10/70 to 9/71	4.4-7.0	6.0-13.0	1.4	0.80-3.70	0.03-0.20
10/69 to 9/70	4.3-5.9	4.2-12.4	0.4-1.0	0.30-3.00	0.06-0.79
10/68 to 9/69	4.8-5.0	6.4-8.2	2.8	0.12-0.90	0.21-0.86
10/67 to 9/68	4.3-4.9	---	---	0.60-2.70	0.01
10/66 to 9/67	---	---	---	---	---
10/65 to 9/66	5.8-7.8	3.3-10.5	4.0-9.0	---	---
10/64 to 9/65	4.9-5.6	---	---	1.40-2.70	0.02-0.13

TABLE 6-5
THE RANGE OF TRACE METAL CONCENTRATIONS FOUND IN THE TOMS RIVER AT U.S.G.S. GAGE STATION 10408500 FOR NEW JERSEY WATER YEARS 1964 TO 1984

Water Year	Total Metals (ug/L)							
	As	Cd	Cr	Cu	Fe	Pb	Hg	Zn
10/83 to 9/84	1-2	1-4	1-2	1-9	370-840	1-10	0.1-0.2	30-56
10/82 to 9/83	1	1-5	1-5	1-4	190-610	1-10	0.1-0.5	14-27
10/81 to 9/82	1	1-5	10	4-7	530-1300	5-10	0.1-0.3	20-80
10/80 to 9/81	1-2	1	10-30	2-11	330-1500	3-13	0.1-0.4	20-40
10/79 to 9/80	1-3	0-8	10	1-4	450-1800	2-18	0.1	20-250
10/78 to 9/79	1-3	0-4	10-30	2-5	440-2100	6-15	0.5	20-70
10/77 to 9/78	0-2	0	10	3-10	400-2700	28	0.5	20-50
10/76 to 9/77	0-2	1-5	10-30	0-17	690-1400	1-57	0-0.5	20-40
10/75 to 9/76	0-2	0-3	0-10	0-10	470-1500	6-14	0.5	10-30
10/74 to 9/75	0-1	0-1	0-40	0-20	400-1500	4-13	0.5-0.6	20-110
10/73 to 9/74	---	---	---	---	1300	10	---	---
10/72 to 9/73	0	2	1	5	640	2	---	8
10/71 to 9/72	1-2	1	12	6	490	5	0	55
10/70 to 9/71	1	---	0	---	480	1	---	40
10/69 to 9/70	0	---	0	10	200-750	---	---	35
10/68 to 9/69	0	---	0	0	850	0	---	30
10/67 to 9/68	---	---	---	---	860	---	---	---
10/66 to 9/67	---	---	---	---	---	---	---	---
10/65 to 9/66	---	---	---	---	---	---	---	---
10/64 to 9/65	---	---	1-6	9-12	260-330	---	---	42-150

Water quality data for the past 20 years show that the waters of the Toms River are acidic, with a pH range of 3.4 to 7.8 and a median pH of 5.0. Surface waters are normally oxygen saturated; however, conditions of oxygen stress occurred in the river during the summer months of Water Years 1966 and 1970, with dissolved oxygen concentrations below the 5.0 mg/L minimum established by NJDEP for riverine waters (N.J.A.C. 7:9-4.1). BOD of the surface waters has remained within the expected concentration range for river water. BOD was greatest during Water Year 1966, with an oxygen demand of 4.0 to 9.0 mg/L. Total nitrogen content of the river shows a trend toward decreasing concentrations over time. Total phosphorus concentrations have remained fairly stable, with a range of 0.01 to 0.20 mg/L. Total phosphorus concentration peaked in Water Years 1969 to 1970, with a maximum concentration of 0.86 mg/L during the summer of 1969 (U.S.G.S. Water-Data: NJ-64-1 to NJ-84-1). Total metal concentrations of As, Cd, Cr, Pb, and Hg for the 20-year period have remained within the permissible concentrations established by NJDEP (N.J.A.C. 7:9-4.1).

Changes in the surface water quality of the Toms River over time may be attributed to increased residential development within the Toms River drainage basin or to industrial development on the Ciba-Geigy Site. Prior to 1966, Ciba-Geigy discharged treated effluents directly to the river; after 1966, treated process water was discharged to the Atlantic Ocean. In September 1977, Ciba-Geigy completed a modernization program of their wastewater treatment facilities. Activated sludge and secondary clarification units replaced the unlined oxidation, settling, and aeration lagoons located adjacent to the river. After the new wastewater treatment plant was operational, aeration lagoons and sludge drying beds were drained and backfilled to grade with soil, as were the settling and oxidation basins. Improved water quality in the Toms River, notably a decrease in nitrogen concentration and a decrease in the BOD, may be related to these changes at the Ciba-Geigy physical plant in conjunction with the improvement of wastewater treatment capabilities (CAI, 1983).

Presently, the pH of the surface waters of the Toms River ranges from 4.4 to 5.6. Dissolved oxygen concentration ranges from 7.9 to 12.0 mg/L. The range of the biochemical oxygen demand (BOD), 0.2 to 1.5 mg/L, is within the BOD range of riverine waters. Nitrogen and phosphorous are present at concentrations that would not limit primary productivity. Dissolved Fe concentrations are within a range of 110 to 220 ug/L. Zn concentrations range from 13 to 29 ug/L. As, Cd, Cr, Cu, and Pb are found at concentrations of less than 10 ug/L each. Hg concentrations range from less than 0.1 to 0.4 ug/L (U.S.G.S. Water-Data: NJ-85-1). All metals are presently within the permissible concentrations established by the NJDEP for surface waters (N.J.A.C. 7:9-4.1).

6.2 Technical Approach

Surface water and sediment sampling programs were initiated to characterize the impact of potential contaminant migration to the Toms River, with contaminants emanating from the Ciba-Geigy Site due to past or present waste disposal practices.

6.2.1 Migratory Pathways

Three potential pathways for contaminant migration into the drainage basin of the Toms River exist at the Ciba-Geigy Site:

- Contaminant migration through groundwater baseflow to the river.
- Contaminant migration through the introduction of treated wastewater to the river.
- Contaminant migration through surface water runoff via intermittent drainage courses to the river.

Groundwater Discharge

Groundwater discharge to the surface waters of the Toms River provides the primary pathway for contaminant migration from the Ciba-Geigy Site, as 70 percent of the surface waters are derived from groundwater baseflow.

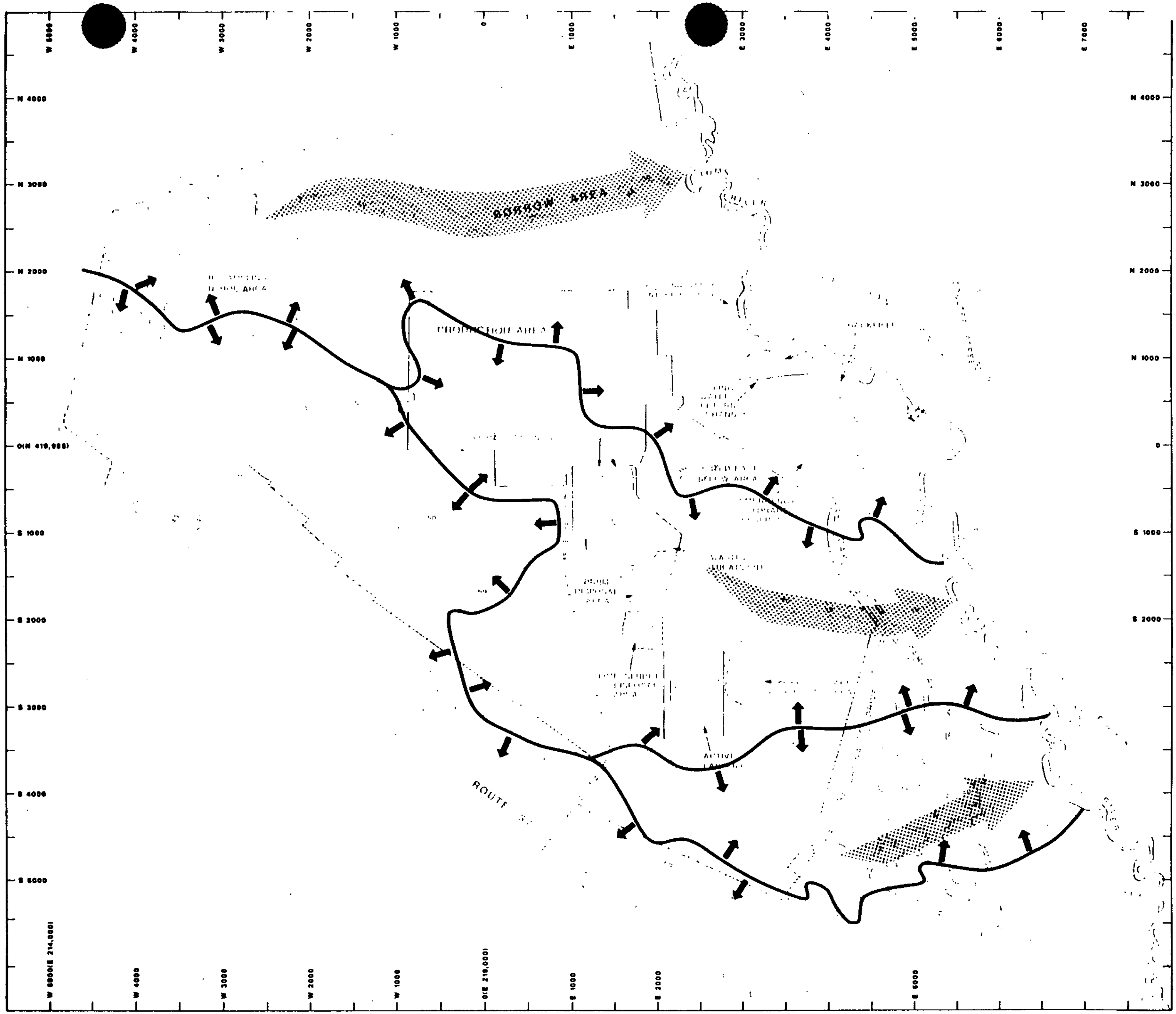
Effluent Discharge

Introduction of effluent waters through NPDES-permitted discharges is a second potential mechanism for contaminant migration into the surface waters of the Toms River. Ciba-Geigy obtains noncontact cooling water from the Toms River at a flow rate of 11 MGD. Two million gallons are used for general housekeeping and boiler feed, then treated and released with other process waters to the ocean outfall. The remainder of the noncontact cooling water (approximately 9 MGD) is returned to the river through the combined cooling water/stormwater discharge channel. Figure 6-3 shows the surface water intake location and discharge points on the Toms River.

Historic discharge of treated effluents from the wastewater treatment plant of the former Toms River Chemical Company also may have provided a pathway for contaminant migration into the Toms River. However, direct discharge of treatment plant effluent to the river ceased in 1966.

Stormwater Runoff

Non-point-source contamination from intermittent drainage courses represents a third contaminant migration pathway into the Toms River. Stormwater runoff in the forested areas of the northern and southern sections of the Ciba-Geigy Site percolates into the soil or follows natural depressions to the river. Intermittent drainage courses at the Ciba-Geigy Site are depicted in Figure 6-3. One intermittent drainage course crosses the Borrow Area in the northern sector of the site. A second drainage course crosses the center portion of the property. This drainage course originates at the wastewater treatment plant to the west and is bounded on the north by the Emergency Storage Reservoir and on the south by the Filtercake Disposal Area. A third drainage course crosses the southeastern sector of the site and encompasses much of the residential development located on Cardinal Drive, immediately off site. Permeability characteristics of on-site soils range from moderately to excessively well drained and highly permeable on the higher ground, to poorly drained along the river. Consequently, perennial streams are not usually formed by surface runoff at the Ciba-Geigy Site.



SURFACE DRAINAGE PATTERNS AT THE CIBA-GEIGY SITE

LEGEND

- RAILROAD SPUR
- SURVEYED BOUNDARY
- BOUNDARY FENCE
- BOUNDARY ROA
- 40 CONTOUR LINE
- 15 SUPPLEMENTAL CONTOUR
- **DRAINAGE DIVIDE**
- **DIRECTION OF SURFACE RUNOFF**

FIGURE 6-3

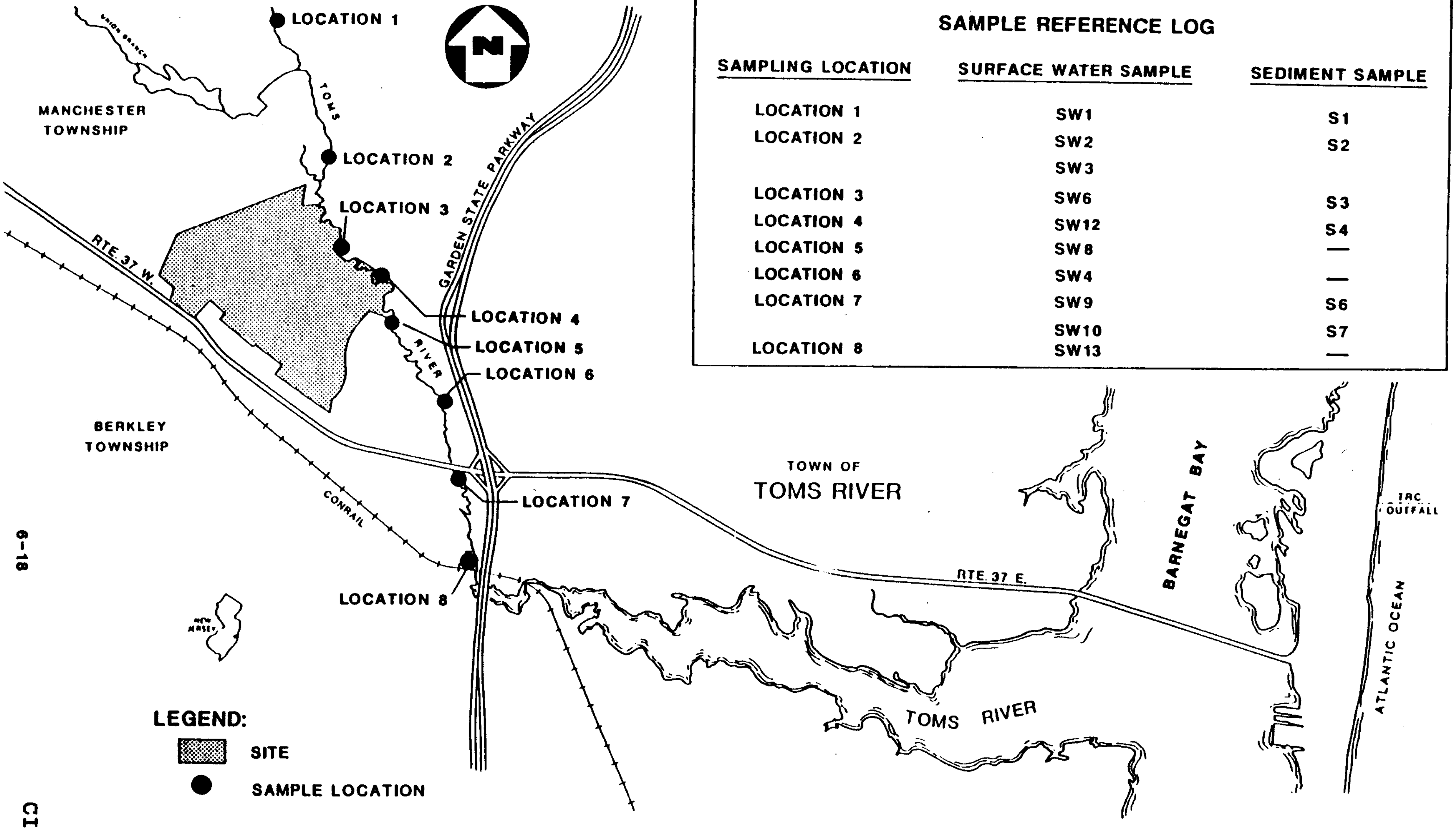
NUS CORPORATION

Locations for the collection of surface soil samples from these intermittent drainage courses crossing the Ciba-Geigy Site are depicted in Chapter 5, Figures 5-2 and 5-3, and summarized in Appendix A-1.

6.2.2 Sampling Strategy

The surface water and sediment sampling program was designed to assess the potential for contaminant migration from the Ciba-Geigy Site into the drainage basin of the Toms River. Surface water and sediment samples were collected from areas upstream from, adjacent to, and downstream from the Ciba-Geigy Site. Eight sampling locations, shown in Figure 6-4, were designated for surface water and stream sediment collection in the Toms River:

o Location 1:	Toms River at Riverwood Park, upstream from the Ciba-Geigy Site.
o Location 2:	Toms River at the Rte. 571 Bridge, upstream from the Ciba-Geigy Site.
o Location 3:	Toms River at the Ciba-Geigy cooling water intake. This sampling station was situated immediately opposite the cooling water intake to intercept potential contaminants from the drainage course crossing the Borrow Area to the north of the site, and to intercept a potential groundwater plume entering the river at this location.
o Location 4:	Toms River in the Ciba-Geigy cooling water discharge channel. This surface water discharge represents the combined flows of noncontact cooling water plus surface water runoff collected from the Ciba-Geigy manufacturing facilities.
o Location 5:	Toms River at the Oak Ridge Parkway Bridge. This sampling was located immediately downstream of the cooling water discharge at the USGS gauge station.
o Location 6:	Toms River adjacent to Cadillac Drive. This sampling station was located immediately downstream of the site near Cadillac Drive to intercept potential contaminants migrating to the river via drainage courses originating near former on-site waste disposal areas. Sampling of this stretch of the river would also intercept a potential groundwater plume.
o Location 7:	Toms River at the Rte. 37 Bridge. This sampling station was located downstream of all stretches of the river directly impacted by the Ciba-Geigy Site to determine the potential downstream extent of any surface water contamination.



SAMPLE REFERENCE LOG

SAMPLING LOCATION	SURFACE WATER SAMPLE	SEDIMENT SAMPLE
LOCATION 1	SW1	S1
LOCATION 2	SW2	S2
	SW3	
LOCATION 3	SW6	S3
LOCATION 4	SW12	S4
LOCATION 5	SW8	—
LOCATION 6	SW4	—
LOCATION 7	SW9	S6
	SW10	S7
LOCATION 8	SW13	—

FIGURE 6-4

SURFACE WATER AND SEDIMENT SAMPLING LOCATIONS

CIBA-GEIGY SITE, DOVER TWP., N.J.

0 1 2 MI.
SCALE

NUS CORPORATION

- Location 8: Toms River north of the confluence with the Sunken Branch, downstream of the potential impacts of the Ciba-Geigy Site.

Strategies for surface water and sediment sampling were designed to maximize sampling at areas where contaminants should occur if present in the Toms River. Surface water samples were collected in the "thalwag" or fastest flowing section of the river. This area was generally midchannel. Further, sampling took place during a period of normal precipitation and normal flow conditions in the Toms River. Weather conditions during surface water and sediment sampling on April 24 through 26, 1985, were clear and dry. No major precipitation was recorded for 3 weeks prior to sampling. Surface water discharge was 105 cf/s, below the annual mean discharge of 135 cf/s for Water Year 1985.

Sediment samples were collected from slack-water areas at each sampling location to ensure that adequate sediment deposits were present. Coarse, open-work streambed materials consisting of sands and gravel were then penetrated to expose fine-grained sediment deposits for sample collection. Sediment samples were collected at a depth of 0 to 12 inches beneath open-work streambed materials.

All aqueous and sediment samples were analyzed under the EPA Contract Laboratory Program for the presence of Hazardous Substance List (HSL) pollutants. In addition to HSL analyses, sediment samples were analyzed for the presence of 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD).

6.3 RI Surface Water Sampling Results

Surface water samples for the analysis of HSL pollutants were collected from the Toms River by NUS Corporation Region 2 FIT on April 24-26, 1985. Aqueous samples were collected from upstream and downstream sampling locations as depicted in Figure 6-4. Appendix A-1 presents a summary of the analytical data.

Organic HSL contaminants were not detected in surface water samples collected from the river at Locations 1 and 2, upstream from the Ciba-Geigy Site. Trichloroethene was detected at concentrations of 5.6 ug/L in the Toms River at

Location 3, adjacent to the Ciba-Geigy cooling water intake. Trichloroethene was also present in trace amounts (i.e., detected at concentrations below the EPA Contract Laboratory Program required quantitation limit, but above the instrument detection limit) at all sampling locations downstream from this point in the river. One other HSL compound, phenol, was detected in the aqueous sample collected from the Ciba-Geigy cooling water channel at Location 4. Phenol was not present in the surface waters downstream from the confluence of the cooling water channel and the Toms River. No other volatile, semivolatile, or pesticide contaminants were detected in the surface waters.

With regard to the above surface water samples collected for organic analyses, positive values of analytes which were also present in the reagent or method blank were disqualified by EPA. Methylene chloride and acetone were detected in the laboratory method blank. Acetone was also detected in the field blank. Further, carbon disulfide, 2-hexanone, methylene chloride, and acetone were disqualified by EPA, as these compounds were misidentified in the volatile fraction. Benzyl alcohol results of all base/neutral fractions were disqualified by EPA due to an incorrect detection limit reported for this compound by the laboratory performing the analyses. Bis(2-ethylhexyl) phthalate was rejected in 3 of 13 samples due to phthalate contamination. Finally, pesticide analyses in surface water sample SW13 were disqualified by EPA due to low surrogate recoveries.

Inorganic compounds detected in the surface waters of the Toms River were present at concentrations normally found in the waters of the Pine Barrens (Means et al., 1981). Iron was detected at concentrations of 400 to 1100 ug/L. Calcium was present at a concentration of 14,000 ug/L in the cooling water discharge channel and found in trace quantities in all upstream and downstream surface waters. Finally, sodium was detected at concentrations of 6000 to 9000 ug/L. Arsenic and thallium data for surface water samples were rejected by EPA because matrix spike recoveries were outside EPA QA/QC limits. Antimony and tin data were rejected because laboratory control samples were outside EPA QA/QC limits. No other metals were detected in the surface waters of the Toms River.

6.4 RI Sediment Sampling Results

Sediment samples for analysis of HSL pollutants and 2,3,7,8-TCDD were collected from the streambed of the Toms River by NUS Corporation Region 2 FIT on April 24-26, 1985. Sediment samples were collected at upstream and downstream sampling locations as depicted in Figure 6-4. Appendix A-1 presents a summary of the analytical data.

Organic HSL contaminants were not detected in sediment samples collected upstream from the Ciba-Geigy Site at Locations 1 and 2. Trace quantities of chlorobenzene were detected in the sediment sample collected at Location 3 in the Toms River adjacent to the cooling water intake. Benzene was present in trace quantities in the sediment samples collected from Location 7 at the Rte. 37 Bridge, downstream from the Ciba-Geigy Site. Sediment sample data for analytes which were also present in the reagent or method blank were disqualified by EPA QA/QC protocol. Methylene chloride, acetone, 2-butanone, toluene, and di-n-butyl phthalate were found in either the reagent blank or the method blank of the laboratory performing the analyses. No other HSL volatile, semivolatile, or pesticide contaminants were detected in sediment samples collected downstream from the Ciba-Geigy Site.

Inorganic compounds detected in the sediments of the Toms River were present at concentrations found in natural soils. Iron was present at concentrations of 580 to 3600 mg/kg. Aluminum was detected in the sediments at concentrations of 200 to 610 mg/kg. Lead was found in concentrations up to 150 mg/kg. Further, copper and zinc were present at concentrations of 50 and 250 mg/kg, respectively, in sediments collected from the Ciba-Geigy cooling water discharge channel. No other metals were detected in the sediments of the Toms River.

Analytical results of the sediment sampling for the presence of 2,3,7,8-TCDD in the Toms River are summarized in Appendix A-1. 2,3,7,8-TCDD was not found in any of the sediment samples collected from the river.

7.4 Conclusions

Aquatic insect populations were not found in the surface waters of the Toms River at Station 3, the confluence of the river and the Ciba-Geigy cooling water discharge channel. The negative impact of the Ciba-Geigy Site upon the aquatic biota at this stretch of the river may be attributed either to thermal fluctuations or to trace levels of organic chemicals in the surface waters. Diversion of surface waters for use as noncontact cooling water at Ciba-Geigy results in a water temperature increase of approximately 10°F before discharge back into the river (OCPB, 1978). As presented in Chapter 6, trichloroethene was present at concentrations of 5.6 ug/L in the surface waters of the river at the Ciba-Geigy cooling water intakes and was found downstream of this point in trace amounts. Further, phenol was present in trace quantities in the waters of the cooling water channel immediately above Station 3 at Oakridge Parkway.

Based upon the results of the biota investigation conducted by NUS Corporation Region 2 FIT, no direct correlation can be made between potential contaminant release from the Ciba-Geigy Site and impacts on the aquatic biota of the Toms River. However, changes in the aquatic community of the Toms River adjacent to the Ciba-Geigy Site were evident. Consequently, further sampling of the aquatic biota of the Toms River is recommended.

8

8.0 QUANTITATIVE BASELINE PUBLIC HEALTH EVALUATION

8.1 Introduction

The public health evaluation conducted for the Ciba-Geigy Site Remedial Investigation (RI) provides a baseline quantitative assessment of the nature of chemical contamination at the site, the contaminant release pathways that could lead to human exposure, and the potential health effects that could be associated, under certain conditions, with that exposure. The evaluation is based on physical, chemical, and other data obtained during the RI and presented in previous chapters. Conclusions from the evaluation will aid in determining the degree of remedial action needed at the site to protect the public health and environment.

The Superfund Public Health Evaluation Manual (EPA, 1986) and the final draft Superfund Exposure Assessment Manual (EPA, 1986a) were consulted for guidance on the process and the level of detail required to conduct such an evaluation. The public health evaluation for the Ciba-Geigy Site addresses

- The selection of indicator chemicals for the public health evaluation.
- The environmental fate and transport of the indicator chemicals.
- The toxicity of the indicator chemicals.
- The routes of exposure for completed pathways.
- The quantitative characterization of potential health risks that could be seen under certain conditions.

This evaluation is limited by the quality of chemical analytical data, the availability of toxicologic data on the compounds detected, the relevance of the toxicologic data to site-specific conditions, and the degree to which human exposure scenarios can be accurately defined. Since human exposure pathways of contaminants emanating from the Ciba-Geigy Site currently indicate minimal human exposure, a quantitative baseline public health evaluation is performed.

8.2 Selection of Indicator Chemicals

The following subsections describe the process used to select indicator chemicals for the quantitative public health evaluation for the Ciba-Geigy Site. Unless indicated, the worksheets used in the process are similar to those described in the Superfund Public Health Evaluation Manual (EPA, 1986).

The indicator chemical selection process evaluates only the chemicals found on the Hazard Substance List (HSL). Each chemical detected at the site was evaluated on the basis of general as well as site-specific transport pathways, its concentration in various media, toxicity, mobility, and persistence in the environment. Those compounds that pose the greatest potential for human exposure (toxicity, mobility, and persistence) are then chosen as indicator chemicals.

The indicator chemical selection process is organized into the following steps:

- Concentrations and Koc Values in Various Environmental Media
- Toxicity Characteristics of Detected Compounds
- Calculation of Contaminant Toxicity (CT) and Indicator Score (IS) Values
- Final Indicator Chemical Selection

8.2.1 Concentration and Koc Values in Various Environmental Media

This section provides the data required for the identification of indicator chemicals. Table 8-1 presents the Chemical Abstract Service (CAS) numbers, organic partition coefficients (Koc), minimum, maximum, and mean concentrations, and frequency of detection of each compound in the various environmental media, respectively. This table contains data that were generated during the RI from April 1985 to September 1986, and include 24 sampling events conducted by NUS Corporation and 36 sampling events conducted by Ciba-Geigy.

TABLE 8-1

CONCENTRATIONS AND Koc VALUES IN VARIOUS ENVIRONMENTAL MEDIA

		Koc	Groundwater (ug/L)				Surface Water (ug/L)				Surface Soil (ug/kg)				Subsurface Soil (ug/kg)				Sediment (ug/kg)				Air (ug/m3)			
Chemical	CAS No.	Value mL/g	Min(1)	Max(2)	Mean	Freq	Min.	Max.	Mean	Freq	Min.	Max.	Mean	Freq	Min.	Max.	Mean	Freq	Min.	Max.	Mean	Freq	Min.	Max.	Mean	Freq
VOLATILES																										
Benzene	71-43-2	83	0.81	3950	222.75	94/621	2.5	68	26.45	10/25									86.0	2250.9	787.65	4/12	1.5	3.19	2.26	12/28
Chlorobenzene	108-90-7	330	0.91	26000	1529.56	191/629	35	330	82.51	8/25	7	790	398.48	2/125	4.3	32000	3161.02	15/94	20.5	4837.15	2152.26	6/12	2.2	16.5	7.28	13/28
Chloroform	67-66-3	31	0.64	4400	272.32	3/150	6.4	150	68.55										77.9	3625.44	1277.47	5/12	6.3	15.1	9.68	7/28
1,2-Dichloroethane	107-06-2	14	6	700	154.10	5/612																				
1,1-Dichloroethene	75-35-4	65	4.5	21	11.08	6/612																				
1,2-Dichloropropane	78-87-5	51	9	30	19.92	6/344										8.9	8.90	1/89								
Ethylbenzene	100-41-4	1100	1.5	3115	526.63	24/612									5.7	19000	4765.88	13/89								
Toluene	108-88-3	300	1	14000	2493.47	81/639					11	4500	1139.46	4/125	5.7	100000	14260.38	25/94		12.96	12.96	1/12				
Trans-1,2-Dichloroethene	540-59-0	59	1	1500	91.89	127/612	6	41	26.35	6/25									13.5	304.36	147.99	4/12				
1,1,1-Trichloroethane	71-55-6	152	3	60	28.62	5/612						7.2	7.20	1/125						322.5	322.50	1/12				
1,1,2,2-Tetrachloroethane	79-34-5	118	5	49	27.62	12/629										50	50.00	1/94		6.75	6.75	1/12				
Tetrachloroethene	127-18-4	364	0.57	12000	813.25	142/612	15	150	59.89	9/25	6	590	185.24	5/125	9	39000	11673.98	7/94	33.74	4782.8	2483.56	6/12				
Trichloroethene	79-01-6	126	0.5	25000	1326.30	183/612	18	520	143.60	11/25									93.99	5706.75	1955.43	8/12	2.4	58	21.20	14/28
Vinyl Chloride	75-01-4	57	4	89	19.57	7/513																				
Total Xylenes	1330-20-7	240	8	44	17.30	6/362						170	170.00	1/125	24	67000	14141.13	16/89	107.5	293.49	213.76	3/12				
Acetone	67-64-1	2.2	5	74500	2278.81	120/350													190.39	413.06	301.74	2/12				
2-Butanone	78-93-3	4.5		356	356.00	1/350					15	98	34.89	7/125	18	730	184.50	12/55								
Carbon Disulfide	75-15-0	54	5	120	19.96	33/350																				
Chloromethane	74-87-3	35	13	220	102.96	3/234																				
2-Hexanone	591-78-6		6	14	8.70	4/350									40	3100	976.00	5/50								
Methylene Chloride	75-09-2	8.8	3.3	280	47.57	20/574									10	6500	970.00	17/44	26.51	652.2	230.01	4/12				
4-Methyl-2-Pentanone	108-10-1		5	13	7.17	5/350									4.9	2800	1233.73	4/50								
Styrene	100-42-5											45	45.00	1/125												
SEMIVOLATILES																										
Aniline	62-53-3		8	8020	1283.08	10/338					1700	1800	1750.00	2/125												
Azobenzene	103-33-3			10	10.00	1/37																				
Benzoic Acid	65-85-0		4	1000	602.00	2/307																				
Benzyl Alcohol	100-51-6		12	3800	1339.88	3/350																				
Di-N-Butylphthalate	84-74-2	170000		1.0	1.00	1/228					1200	4500	2936.36	11/55	410	4600	2377.5	4/39								
Bis(2-Chloroethyl)Ether	111-44-4	13.9		13	13.00	1/228																				
4-Chloroaniline	106-47-8		10	17	13.37	2/228																				
2-Chloronapthalene	91-58-7		13	19	16.24	2/228									670	5000	1887.5	4/39								
2-Chlorophenol	95-57-8		12	100	40.00	4/314																				
4-Chloro-3-Methylphenol	59-50-7			12	12.00	1/308																				
1,2-Dichlorobenzene	95-50-1	1700	1.3	10000	691.26	101/629	14	45	24.21	5/25	2500	5100	3799.95	3/125	1.8	120000	20180.80	13/44								
1,3-Dichlorobenzene	541-73-1	1700	3	130	31.16	12/520																				
1,4-Dichlorobenzene	106-46-7	1700	2.4	140	31.40	18/520									2000	23000	10366.70	3/44								
Bis(2-Ethylhexyl)Phthalate	117-81-7		18	530	83.91	16/350					430	8700	2378.38	6/125	650	18000	3843.80	8/39								
Hexachloroethane	67-72-1	20000		14	14.00	1/484																				
Naphthalene	91-20-3		2.9	920	123.75	46/616					2600	4200	3400.10	2/125	3000	120000	20491.70	12/39								
4-Methylphenol	106-44-5	500(3)	36	85	60.50	2/313																				
4-Nitroaniline	100-01-6			34	34.00	1/370																				
Nitrosodimethylamine	62-75-9	0.1		30	30.00	1/430																				
Nitrobenzene	98-95-3	36	5	39000	5292.23	30/616		10	10.00	1/18		390	390.00	2/125	1300	1800	1550.00	2/44								
Di-N-Octyl Phthalate	117-84-0		16	24	20.00	2/385																				

TABLE 8-1 (continued)

CONCENTRATIONS AND Koc VALUES IN VARIOUS ENVIRONMENTAL MEDIA

Chemical	CAS No.	Koc Value mL/g	Groundwater (ug/L)				Surface Water (ug/L)				Surface Soil (ug/kg)				Subsurface Soil (ug/kg)				Sediment (ug/kg)				Air (ug/m3)			
			Min(1)	Max(2)	Mean	Freq	Min.	Max.	Mean	Freq	Min.	Max.	Mean	Freq	Min.	Max.	Mean	Freq	Min.	Max.	Mean	Freq	Min.	Max.	Mean	Freq
Phenol	108-95-2	14.2	12	496	215.78	4/313																				
1,2,4-Trichlorobenzene	120-82-1	9200	10	4100	312.67	47/507		18	18.00	1/18	420	6500	3110.01	7/125	420	130000	34651.46	14/89								
2,4,5-Trichlorophenol	95-95-4	89													21.5	3800	966.13	4/55								
2-Methylphenol	95-48-7	500(3)	14	632	323.00	2/313																				
Anthracene	120-12-7	14000									350	12000000	2001836.79	12/125	700	5500	3087.50	8/39								
Butyl Benzyl Phthalate	85-68-7										1300	6300	3766.68	6/55		940	940	1/39								
Fluoranthene	206-44-0	38000									500	77000	17949.98	6/125	980	2200	1590.00	2/39								
Pyrene	129-00-0	38000		80	80.00	1/37					500	59000	21000.00	4/125		2000	2000.00	1/39								
Phenanthrene	85-01-8	14000									370	45000	8663.28	6/125	530	79000	23845.63	16/89								
Chrysene	218-01-9	200000									700	35000	12233.37	3/125		800	800.00	1/39								
Benzo(b)Fluoranthene	205-99-2	550000									980	58000	15919.93	4/125		570	570.00	1/39								
Benzo(k)Fluoranthene	207-08-9	550000									980	60000	21093.33	3/125		600	600.00	1/39								
Benzo(a)Pyrene	50-32-8	5500000									830	29000	14914.90	2/70												
Indeno(1,2,3cd)Pyrene	193-39-5	1600000										520	520.00	1/70												
Benzo(ghi)Perylene	191-24-2	1600000										560	560.00	1/70												
PESTICIDES																										
4,4-DDT	50-29-3	243000									6.1	300	34.22	29/125												
4,4-DDE	72-55-9	4400000									1	10	6.28	9/125												
Heptachlor Epoxide	1024-57-3	220									22	340	173.78	4/125												
Endosulfan II	33213-65-9										110	9000	3442.01	5/55												
Dieldrin	60-57-1	1700										6	6.00	1/55												
Chlordane	57-74-9	140000										80	80.00	1/55												
Aroclor 1016	12674-11-2	530000(4)										50	50.00	1/55												
Aroclor 1221	11104-28-2	530000(4)										80	80.00	1/55												
Aroclor 1232	11141-16-5	530000(4)										80	80.00	1/55												
Aroclor 1242	53469-21-9	530000(4)										50	50.00	1/55												
Aroclor 1248	12672-29-6	530000(4)										50	50.00	1/55												
Aroclor 1254	11097-69-1	530000(4)										80	80.00	1/55												
Aroclor 1260	11096-82-5	530000(4)										80	80.00	1/55												
INORGANICS																										
Aluminum	7429-90-5		200	38000	3402.85	147/253		500	500.00	1/13	2.26E+05	5.06E+07	4.77E+06	125/125	5.05E+05	5.20E+07	1.05E+07	50/50	200000	6.10E+05	3.03E+05	4/6				
Antimony	7440-36-0		34	63	48.69	3/253					3.90E+04	5.70E+04	4.72E+04	5/125	6.70E+03	4.00E+04	1.87E+04	3/53								
Arsenic	7440-38-2		11.3	16	13.33	4/488					6.10E+03	6.50E+04	1.53E+04	17/125	6.20E+03	1.61E+05	5.40E+04	12/135								
Barium	7440-39-3		25	395	91.99	31/410																				
Beryllium	7440-41-7		5	18	12.52	4/171						1.22E+05	1.22E+05	1/125												
Cadmium	7440-43-9		5	345	19.90	72/410					3.10E+03	2.00E+04	8.98E+03	3/125	1.10E+01	7.50E+05	7.80E+04	10/85								
Calcium	7440-70-2		0.8	138900	20508.95	141/410		14000	14000.00	2/13	2.26E+06	2.03E+07	9.73E+06	10/125	3.26E+06	1.95E+07	8.20E+06	23/50								
Chromium	7440-47-3		3	318	37.82	190/488					5.40E+03	4.87E+06	2.54E+05	86/125	3.80E+01	1.80E+06	3.94E+05	73/135								
Cobalt	7440-48-4		6	59	30.77	12/253																				
Copper	7440-50-8		21	560	92.18	162/472					1.50E+04	4.44E+06	6.86E+05	36/125	3.10E+01	1.80E+06	6.19E+05	69/103		5.00E+04	5.00E+04	1/6				
Iron	7439-89-6		340	1600000	49720.58	260/488	400	1100	783.00	9/13	5.15E+05	1.18E+08	7.05E+06	125/125	2.30E+05	5.00E+07	9.79E+06	50/50	580000	3.60E+06	1.38E+06	6/6				
Lead	7439-92-1		1	328	46.55	233/488					2.90E+03	6.50E+04	1.30E+04	80/125	1.20E+02	3.21E+05	9.57E+04	63/135	6100	1.50E+05	5.80E+04	[illegible]				

TABLE 8-1 (continued)

CONCENTRATIONS AND Koc VALUES IN VARIOUS ENVIRONMENTAL MEDIA

			Groundwater (ug/L)				Surface Water (ug/L)				Surface Soil (ug/kg)				Subsurface Soil (ug/kg)				Sediment (ug/kg)				Air (ug/m3)			
Chemical	CAS No.	Koc Value mL/g	Min(1)	Max(2)	Mean	Freq	Min.	Max.	Mean	Freq	Min.	Max.	Mean	Freq	Min.	Max.	Mean	Freq	Min.	Max.	Mean	Freq	Min.	Max.	Mean	Freq
Lithium	7439-93-2		10	86	24.68	17/115																				
Magnesium	7439-95-4		1060	142000	27229.86	73/413					3.44E+06	3.58E+07	1.39E+07	11/125	5.80E+06	3.04E+07	1.44E+07	17/50								
Manganese	7439-96-5		18	4695	441.36	195/410		20	20.00	1/13	8.30E+03	2.91E+05	4.19E+04	77/125	7.60E+03	4.79E+05	1.03E+05	46/50								
Mercury	7439-97-6		0.2	12	1.10	47/488					1.10E+02	3.00E+05	3.59E+04	61/125	1.20E+02	2.40E+05	2.39E+04	66/135								
Nickel	7440-02-0		21	612	76.09	73/410					2.20E+04	4.60E+04	3.06E+04	12/125	4.00E+01	2.00E+05	1.94E+04	19/103								
Potassium	7440-09-7		4180	137800	9008.26	61/410																				
Selenium	7782-49-2		6	31	14.34	3/265					7.10E+03	7.90E+03	7.35E+03	2/125	1.00E+03	5.80E+03	3.07E+03	7/85								
Silver	7440-22-4														5.40E+03	3.70E+04	1.69E+04	3/135								
Sodium	7440-23-5		4000	251000	29792.86	127/410	6000	16000	8444.17	6/13																
Tin	7440-31-5		50	88	71.16	3/216					2.80E+04	1.10E+05	6.48E+04	8/125												
Vanadium	7440-62-2		29	233	74.71	7/273					2.70E+04	1.41E+05	5.96E+04	21/125	3.50E+04	2.10E+05	7.59E+04	17/50								
Zinc	7440-66-6		20	3660	362.80	240/488					1.00E+04	1.77E+06	2.14E+05	47/125	3.80E+01	6.46E+05	1.12E+05	48/103		2.50E+05	2.50E+05	1/6				

NOTES:

(1) Minimum value of detected concentrations
(2) Maximum concentrations
(3) Koc value for Cresol, CAS No. 1319-77-33, used.
(4) Koc for Polychlorinated Biphenyls, CAS No. 1336-36-3, used.

A chemical's Koc value is used as a relative indication of environmental mobility. In general, compounds with Koc values greater than 1000 would be tightly bound to organic matter in soils and considered to be immobile. Compounds with Koc values of 100 or less are believed to be moderately to highly mobile (Kenaga, 1980), and have a higher potential to leach through soil to the groundwater or to be incorporated in runoff to surface waters.

Minimum, maximum, and mean concentrations are recorded for each compound in the different media. Sample media include groundwater, surface water, surface soil, subsurface soil, sediments, and air. The minimum concentration is the lowest quantified concentration. The maximum concentration is the highest quantified concentration. The mean concentration is the arithmetic mean of all samples within a medium. The frequency of detection presents the number of positive values versus the total number of samples and is also listed for each chemical within a medium.

8.2.2 Toxicity Characteristics of Detected Compounds

This section presents the toxicity characteristics of all compounds detected. Compounds detected were categorized by their potential carcinogenic and/or noncarcinogenic effects. Table 8-2 provides the toxicity constants for potential carcinogenic compounds, and Table 8-3 provides the toxicity constants for noncarcinogenic compounds. Only those compounds for which data are available in EPA, 1986 and IRIS, 1987 are included in these tables.

Toxicity constants for use with drinking water concentrations are referred to as wT, those for concentrations in soil are sT, and those for concentrations in air are aT. Toxicity constants for potential carcinogens (wTc, sTc, aTc) were based on the dose of the particular chemical in which a 10 percent incremental carcinogenic response was observed. Toxicity constants for noncarcinogens (wTn, sTn, aTn) were derived from the minimum effective dose for chronic effects, a severity of effect factor (RVe), and standard factors for body weight and oral or inhalation intake.

TABLE 8-2

TOXICITY CONSTANTS FOR POTENTIAL CARCINOGENIC COMPOUNDS

	Toxicity Constants for Carcinogenic Effects		
Chemical	Water (wTc) L/mg	Soil (sTc) kg/mg	Air (aTc) m3/mg
VOLATILES			
Benzene	7.71E-03	3.86E-07	7.71E-02
Chloroform	5.63E-02	2.81E-06	5.63E-01
1,2-Dichloroethane	5.86E-02	2.93E-06	5.86E-01
1,1-Dichloroethene	1.23E-01	6.14E-06	1.23E+00
1,1,2,2-Tetrachloroethane	4.74E-02	2.37E-06	4.74E-01
Tetrachloroethene	8.86E-03	4.43E-07	8.86E-02
Trichloroethene	4.29E-03	2.14E-07	4.29E-02
Vinyl chloride	4.29E-03	2.14E-07	4.29E-02
Chloromethane	2.71E-03	1.36E-07	2.71E-02
SEMIVOLATILES			
Bis(2-Chloroethyl)ether	3.47E-01	1.74E-05	3.47E+00
Bis(2-Ethylhexyl)phthalate	5.71E-04	2.68E-08	5.71E-03
Hexachloroethane	2.29E-03	1.14E-07	2.29E-02
Chrysene	NL (1)	NL	NL
Benzo(b)flouranthene	NL	NL	NL
Benzo(a)pyrene	4.55E+00	2.28E-04	4.55E+01
Indeno(1,2,3cd)pyrene	NL	NL	NL
PESTICIDES			
4,4-DDT	1.59E-01	7.97E-06	1.59E+00
4,4-DDE	1.13E-01	5.64E-06	1.13E+00
Heptachlor epoxide	8.28E+00	4.14E-04	8.28E+01
Dieldrin	3.66E+00	1.83E-04	3.66E+01
Chlordane	4.32E-01	2.16E-05	4.32E+00
INORGANICS			
Arsenic	4.07E+00	2.03E-04	4.07E+01
Beryllium	NL	NL	2.28E+01
Cadmium	NL	NL	1.65E+01
Chromium	NL	NL	1.11E+02
Nickel	NL	NL	2.85E+00

NOTE:

(1) Compound is not listed in EPA, 1986 or IRIS, 1987.

TABLE 8-3

TOXICITY CONSTANTS FOR NONCARCINOGENIC COMPOUNDS

	Toxicity Constants for Noncarcinogenic Effects		
Compound	Water (wTn) L/mg	Soil (sTn) kg/mg	Air (aTn) m3/mg
VOLATILES			
Benzene	1.17E-01	5.85E-06	1.18E+02
Chlorobenzene	1.43E-01	7.14E-06	2.79E-01
1,2-Dichloroethane	1.76E-02	8.80E-07	1.10E+00
1,1-Dichloroethene	3.71E-01	1.86E-05	5.65E+00
1,2-Dichloropropane	1.00E-01	5.00E-06	1.00E+00
Ethylbenzene	1.10E-02	5.52E-07	1.10E-01
Toluene	5.20E-03	2.60E-07	5.20E-02
Trans-1,2-dichloroethene	5.29E-02	2.65E-06	5.29E-01
1,1,1-Trichloroethane	7.33E-04	3.67E-08	7.33E-03
1,1,2,2-Tetrachloroethane	4.55E-01	2.27E-05	4.55E+00
Tetrachloroethene	9.62E-03	4.81E-07	2.75E-02
Trichloroethene	1.05E+00	5.26E-05	2.96E+01
Vinyl chloride	8.77E-02	4.39E-06	8.77E-01
Carbon disulfide	4.24E-01	2.12E-05	4.24E+00
Chloromethane	9.05E-02	4.52E-06	9.05E-01
Methylene chloride	9.20E-04	4.60E-08	9.20E-03
SEMIVOLATILES			
Di-n-butylphthalate	3.81E-02	1.90E-06	3.81E-01
1,2-Dichlorobenzene	5.19E-02	2.60E-06	3.61E-01
1,3-Dichlorobenzene	5.19E-02	2.60E-06	3.61E-01
1,4-Dichlorobenzene	5.19E-02	2.60E-06	3.61E-01
Hexachloroethane	6.62E-03	3.31E-07	4.45E-01
Phenol	1.00E-01	5.02E-06	2.49E+00
1,2,4-Trichlorobenzene	2.14E-01	1.07E-05	1.52E+00
2,4,5-Trichlorophenol	1.02E-01	5.10E-06	1.02E+00
Benzo(a)pyrene	2.67E+01	1.33E-03	1.91E+01
INORGANICS			
Antimony	4.35E+00	2.17E-04	2.29E+02
Arsenic	1.80E+01	9.00E-04	1.80E+02
Barium	4.08E+00	2.04E-04	4.08E+01
Cadmium	4.45E+00	2.23E-04	3.59E+02
Copper	7.14E-01	3.57E-05	7.14E+00
Lead	8.93E-01	4.46E-05	8.93E+00
Mercury	1.84E+01	9.21E-04	1.86E+02
Nickel	4.26E+00	2.13E-04	1.57E+02
Selenium	1.05E+02	5.26E-03	1.05E+03
Silver	2.00E+01	1.00E-03	2.00E+02
Vanadium	1.43E-01	7.14E-06	1.43E+00
Zinc	1.07E-01	5.33E-06	1.07E+00

Toxicity constant units are the inverse of their respective concentration units so that in the calculation of the indicator scores the values will be unitless. The indicator score is a ratio between a measured concentration and a toxicity-based concentration benchmark that is used to rank the site chemicals.

Some of the chemicals that were classified as potential carcinogens also had noncarcinogenic effects and were scored for both effects. However, eight chemicals that were classified as potential carcinogens (chloroform, bis(2-chloroethyl) ether, bis(2-ethylhyxl) phthalate, 4,4'-DDT, 4,4'-DDE, heptachlor epoxide, dieldrin, and chlordane) did not have toxicity constants for their noncarcinogenic effects and therefore, these compounds were only rated for their carcinogenic effects. Compounds for which carcinogenic and noncarcinogenic toxicity constants were not available could not be scored or ranked, and therefore were not further evaluated.

8.2.3 Calculation of Contaminant Toxicity (CT) and Indicator Score (IS) Values

The calculations of the contaminant toxicity and indicator scores were based on the maximum and mean concentrations of each detected compound. Contaminant toxicity (CT) values were calculated for each compound by multiplying the carcinogenic and noncarcinogenic toxicity constants from Tables 8-2 and 8-3 by their maximum and mean concentrations from Table 8-1 within each medium. Tables 8-4 and 8-5 present the CT values, the IS, and the tentative rank for the potential carcinogenic and noncarcinogenic compounds. The IS value is the sum of the CT values for each medium (water, soil, and air) for each chemical, keeping maximum and mean values separate. For each medium only the highest CT value was used in the calculation of the IS.

8.2.4 Final Indicator Chemical Selection

The indicator chemicals selected for the Ciba-Geigy Site focused on those compounds that appeared in groundwater, have a history of use and disposal at the site, had been found in private wells off site, and had high IS based on maximum or mean concentrations.

TABLE 8-4

CALCULATION OF CT AND IS VALUES FOR CARCINOGENIC EFFECTS

Compound	Groundwater CT		Surface Water CT		Surface Soil CT		Sub-Surface Soil CT		Sediment CT		Air CT		Indicator Score (IS) Value		Tentative Rank	
	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean
VOLATILES																
Benzene	3.05E-02	1.72E-03	5.24E-04	2.04E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.69E-07	3.04E-07	0.00E+00	0.00E+00	3.05E-02	1.72E-03	6	8
Chloroform	2.48E-01	1.53E-02	8.45E-03	3.86E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.02E-05	3.59E-06	0.00E+00	0.00E+00	2.48E-01	1.53E-02	1	2
1,2-Dichloroethane	4.10E-02	9.03E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.10E-02	9.03E-03	5	3
1,1-Dichloroethene	2.58E-03	1.36E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.58E-03	1.36E-03	9	9
1,1,2,2-Tetrachloroethane	2.32E-03	1.31E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.19E-07	1.19E-07	1.60E-08	1.60E-08	0.00E+00	0.00E+00	2.32E-03	1.31E-03	10	10
Tetrachloroethene	1.06E-01	7.21E-03	1.33E-03	5.31E-04	2.61E-07	8.21E-08	1.73E-05	5.17E-06	2.12E-06	1.10E-06	0.00E+00	0.00E+00	1.06E-01	7.21E-03	3	4
Trichloroethene	1.07E-01	5.69E-03	2.23E-03	6.16E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.22E-06	4.18E-07	0.00E+00	0.00E+00	1.07E-01	5.69E-03	2	5
Vinyl chloride	3.82E-04	8.40E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.82E-04	8.40E-05	12	12
Chloromethane	5.96E-04	2.79E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.96E-04	2.79E-04	11	11
SEMIVOLATILES																
Bis(2-chloroethyl)ether	4.51E-03	4.51E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.51E-03	4.51E-03	8	6
Bis(2-ethylhexyl)phthalate	3.03E-04	4.79E-05	0.00E+00	0.00E+00	2.33E-07	6.37E-08	4.82E-07	1.03E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.03E-04	4.80E-05	13	14
Hexachloroethane	3.21E-05	3.21E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.21E-05	3.21E-05	15	15
Chrysene (1)																
Benzo(b)fluoranthene (1)																
Benzo(a)pyrene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.61E-03	3.40E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.61E-03	3.40E-03	7	7
Indeno(1,2,3cd)pyrene (1)																
PESTICIDES																
4,4-DDT	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.39E-06	2.73E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.39E-06	2.73E-07	16	18
4,4-DDE	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.64E-08	3.54E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.64E-08	3.54E-08	19	19
Heptachlor epoxide	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.41E-04	7.19E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.41E-04	7.19E-05	14	13
Dieldrin	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.10E-06	1.10E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.10E-06	1.10E-06	18	17
Chlordane	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.73E-06	1.73E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.73E-06	1.73E-06	17	16
INORGANICS																
Arsenic	6.51E-02	5.43E-02	0.00E+00	0.00E+00	1.32E-02	3.11E-03	3.27E-02	1.10E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.78E-02	6.52E-02	4	1
Beryllium (2)																
Cadmium (2)																
Chromium (2)																
Nickel (2)																

NOTE:

(1) Toxicity values, wTc and sTc, were not available for chrysene, benzo(b)flouranthene, and indeno(1,2,3cd)pyrene. Therefore, CT and IS values were not calculated.

(2) Toxicity values, wTc and sTc, were not available for beryllium, cadmium, chromium, and nickel. Therefore, CT and IS values were not calculated.

TABLE 8-5

CALCULATION OF CT AND IS VALUES FOR NONCARCINOGENIC EFFECTS

Compound	Groundwater CT		Surface Water CT		Surface Soil CT		Sub-Surface Soil CT		Sediment CT		Air CT		Indicator Score (IS) Value		Tentative Rank	
	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean
VOLATILES																
Benzene	4.62E-01	2.61E-02	7.96E-03	3.09E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.32E-05	4.61E-06	3.76E-01	2.67E-01	8.39E-01	2.93E-01	8	5
Chlorobenzene	3.72E+00	2.19E-01	4.72E-02	1.18E-02	5.64E-06	2.85E-06	2.28E-04	2.86E-05	3.45E-05	1.54E-05	4.60E-03	2.03E-03	3.72E+00	2.21E-01	2	8
1,2-Dichloroethane	1.23E-02	2.71E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.23E-02	2.71E-03	27	28
1,1-Dichloroethene	7.79E-03	4.11E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.79E-03	4.11E-03	29	27
1,2-Dichloropropane	3.00E-03	1.99E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.45E-08	4.45E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.00E-03	1.99E-03	32	29
Ethylbenzene	3.43E-02	5.79E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.05E-05	2.63E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.43E-02	5.80E-03	24	25
Toluene	7.28E-02	1.30E-02	0.00E+00	0.00E+00	1.17E-06	2.96E-07	2.60E-05	3.71E-06	3.37E-09	3.37E-09	0.00E+00	0.00E+00	7.28E-02	1.30E-02	18	19
Trans-1,2-Dichloroethene	7.94E-02	4.86E-03	2.17E-03	1.39E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.07E-07	3.92E-07	0.00E+00	0.00E+00	7.94E-02	4.86E-03	17	26
1,1,1-Trichloroethane	4.40E-05	2.10E-05	0.00E+00	0.00E+00	2.64E-10	2.64E-10	0.00E+00	0.00E+00	1.18E-08	1.18E-08	0.00E+00	0.00E+00	4.40E-05	2.10E-05	36	36
1,1,2,2-Tetrachloroethane	2.23E-02	1.26E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.14E-06	1.14E-06	1.53E-07	1.53E-07	0.00E+00	0.00E+00	2.23E-02	1.26E-02	25	20
Tetrachloroethene	1.15E-01	7.82E-03	1.44E-03	5.76E-04	2.84E-07	8.91E-08	1.88E-05	5.62E-06	2.30E-06	1.19E-06	0.00E+00	0.00E+00	1.15E-01	7.83E-03	16	24
Trichloroethene	2.63E+01	1.39E+00	5.46E-01	1.51E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.00E-04	1.03E-04	1.72E+00	6.28E-01	2.80E+01	2.02E+00	1	1
Vinyl chloride	7.81E-03	1.72E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.81E-03	1.72E-03	28	30
Carbon disulfide	5.09E-02	8.46E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.09E-02	8.46E-03	19	23
Chloromethane	1.99E-02	9.32E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.99E-02	9.32E-03	26	22
Methylene chloride	2.58E-04	4.38E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.99E-07	4.46E-08	3.00E-08	1.06E-08	0.00E+00	0.00E+00	2.58E-04	4.38E-05	33	34
SEMIVOLATILES																
Di-N-butylphthalate	3.81E-05	3.81E-05	0.00E+00	0.00E+00	8.55E-06	5.58E-06	8.74E-06	4.52E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.68E-05	4.37E-05	35	35
1,2-Dichlorobenzene	5.19E-01	3.59E-02	2.34E-03	1.26E-03	1.33E-05	9.88E-06	3.12E-04	5.25E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.19E-01	3.59E-02	10	15
1,3-Dichlorobenzene	6.75E-03	1.62E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.75E-03	1.62E-03	31	32
1,4-Dichlorobenzene	7.27E-03	1.63E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.98E-05	2.70E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.33E-03	1.66E-03	30	31
Hexachloroethane	9.27E-05	9.27E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.27E-05	9.27E-05	34	33
Phenol	4.96E-02	2.16E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.96E-02	2.16E-02	20	16
1,2,4-Trichlorobenzene	8.77E-01	6.69E-02	3.85E-03	3.85E-03	6.96E-05	3.33E-05	1.39E-03	3.71E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.79E-01	6.73E-02	7	11
2,4,5-Trichlorophenol	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.94E-05	4.93E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.94E-05	4.93E-06	37	37
Benzo(a)pyrene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.86E-02	1.98E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.86E-02	1.98E-02	21	17
INORGANICS																
Antimony	2.74E-01	2.12E-01	0.00E+00	0.00E+00	1.24E-02	1.08E-02	8.68E-03	4.06E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.86E-01	2.22E-01	15	7
Arsenic	2.88E-01	2.40E-01	0.00E+00	0.00E+00	5.85E-02	1.38E-02	1.45E-01	4.86E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.33E-01	2.89E-01	12	6
Barium	1.61E+00	3.75E-01	0.00E+00	0.00E+00	2.49E-02	2.49E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.64E+00	4.00E-01	6	3
Cadmium	1.54E+00	8.86E-02	0.00E+00	0.00E+00	4.46E-03	2.00E-03	1.67E-01	1.74E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.70E+00	1.06E-01	5	9
Copper	4.00E-01	6.58E-02	0.00E+00	0.00E+00	1.59E-01	2.45E-02	6.43E-02	2.21E-02	1.79E-03	1.79E-03	0.00E+00	0.00E+00	5.58E-01	9.03E-02	9	10
Lead	2.93E-01	4.16E-02	0.00E+00	0.00E+00	2.90E-03	5.80E-04	1.43E-02	4.27E-03	6.69E-03	2.59E-03	0.00E+00	0.00E+00	3.07E-01	4.58E-02	14	13
Mercury	2.21E-01	2.03E-02	0.00E+00	0.00E+00	2.76E-01	3.31E-02	2.21E-01	2.20E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.97E-01	5.34E-02	11	12
Nickel	2.61E+00	3.24E-01	0.00E+00	0.00E+00	9.80E-03	6.52E-03	4.26E-02	4.13E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.65E+00	3.31E-01	4	4
Selenium	3.26E+00	1.51E+00	0.00E+00	0.00E+00	4.16E-02	3.87E-02	3.05E-02	1.62E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.30E+00	1.54E+00	3	2
Silver	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.70E-02	1.69E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.70E-02	1.69E-02	22	18
Vanadium	3.33E-02	1.07E-02	0.00E+00	0.00E+00	1.01E-03	4.26E-04	1.50E-03	5.42E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.48E-02	1.12E-02	23	21
Zinc	3.92E-01	3.88E-02	0.00E+00	0.00E+00	9.43E-03	1.14E-03	3.44E-03	5.96E-04	1.33E-03	1.33E-03	0.00E+00	0.00E+00	4.01E-01	4.02E-02	13	14

The final list of indicator chemicals for the Ciba-Geigy Site is:

Carcinogens

- Arsenic
- Benzene
- Chloroform
- 1,2-Dichloroethane
- Tetrachloroethene
- Trichloroethene

Noncarcinogens

- Barium
- Cadmium
- Chlorobenzene
- Nickel
- 1,2,4-Trichlorobenzene

Benzo(a)pyrene, bis(2-chloroethyl)ether, selenium, and 1,2-dichlorobenzene were not selected as indicator chemicals for the reasons described below.

Benzo(a)pyrene is not on the final indicator chemical list of carcinogens because it did not appear in any groundwater samples, it only appeared twice out of seventy surface soil samples, and its chemical-physical characteristics indicate that it was not likely to volatilize or migrate off site in an aqueous medium.

Bis(2-chloroethyl)ether is not on the final indicator chemical list of carcinogens because it appeared only once in 191 groundwater sampling events. Its concentration in the groundwater was such that volatilization would yield a concentration in air well below the Threshold Limit Value - Short Term Exposure Limit (TLV-STEL).

1,2-Dichlorobenzene (1,2-DCB) is not on the final indicator chemical list of noncarcinogens because the highest detected concentration in the groundwater was 87 ppb (ug/L), which is well below the recommended maximum contaminant level of 620 ppb and the ambient water quality criterion of 400 ppb (EPA, 1986).

Selenium (Se) is not on the final indicator chemical list of noncarcinogens because it appeared only twice in 71 groundwater analyses. In addition, it appeared only twice in 70 surface soil analyses.

Arsenic, benzene, and trichloroethene are classified as potential carcinogens and are not in the final indicator chemical list of noncarcinogens. Since these potential carcinogens are not characterized by any threshold limit, the derivation of acceptable intake values for subchronic, chronic, or daily exposures (AIS, AIC, or ADI) would be inappropriate.

8.3 Environmental Fate and Transport of Indicator Chemicals

The environmental fate and transport characteristics of compounds released into the environment are important factors for assessing the potential health effects of detected compounds for specific site-related conditions. Fate and transport characteristics are determined by a number of factors including volatility, solubility, reactivity, sorption capacity, bioaccumulation, and biotransformation. Table 8-6 lists some of the chemical and physical properties of the indicator chemicals. As shown in the table, environmental fate and transport characteristics are naturally divided between organic and inorganic compounds. Generally, the organic compounds are more likely to volatilize into air or dissolve in water; inorganic compounds are more persistent in soils. Specific environmental fate and transport data are provided for all the organic and inorganic indicator chemicals (EPA, 1985).

8.3.1 Definitions of Terms

The following are terms which must be clearly defined in order to evaluate the fate and transport characteristics of each indicator chemical.

8.3.1.1 Volatilization

Vapor pressure and Henry's Law constant are two measures of chemical volatility and thus, are important in evaluating air exposure pathways. Vapor pressure is a relative measure of the volatility of a chemical in its pure state. Henry's Law constant, which combines vapor pressure with solubility and molecular weight, is more appropriate for estimating releases to air from contaminated water and should be used to evaluate chemicals for which this type of pathway is expected.

TABLE 8-6

CHEMICAL AND PHYSICAL PROPERTIES OF INDICATOR CHEMICALS(a)

Chemical	Henry's Law Constant (atm/m3/mole)	Vapor Pressure (mm Hg)	Water Solubility (mg/L)	Specific Gravity(b)	Koc (mL/g)	log Kow	Low Half-Life Ranges (days) GW	SW	SOIL	AIR
ORGANICS										
Benzene	5.59E-03	9.52E+01	1.75E+03	0.8787 (15/4 C)	83	2.12		1.00		6.00
Chlorobenzene	3.72E-03	1.17E+01	4.66E+02	1.107 (20/4 C)	330	2.84		0.30		3.50
Chloroform	2.87E-03	1.51E+02	8.20E+03	1.484 (20/20 C)	31	1.97		0.30		80.00
1,2-Dichloroethane	9.78E-04	6.40E+01	8.52E+03	1.2569 (20/4 C)	14	1.48		0.17		36.00
Tetrachloroethene	2.59E-02	1.78E+01	1.50E+02	1.6230 (20/4 C)	364	2.60		1.00		47.00
1,2,4-Trichlorobenzene	2.31E-03	2.90E-01	3.00E+01	1.454 (20/4 C)	9200	4.30		1.20		
Trichloroethene	9.10E-03	5.79E+01	1.10E+03	1.4649 (20/4 C)	126	2.38		1.00		3.70
INORGANICS										
Arsenic				5.727 (14 C)				PERS(c)		5.00
Barium				3.51 (20 C)				PERS(c)		4.80
Cadmium				8.65 (20 C)				PERS(c)		4.80
Nickel				8.90 (25 C)						

NOTES:

a) Values from EPA, 1986

b) Specific gravity values from:

CRC Handbook of Chemistry and Physics, 62nd Ed., 1981-82, CRC Press.

The values for specific gravity are followed by parentheses. The value within the parenthese indicate the temperature of the given chemical at X degrees Celsius relative to the density of water at Y degrees Celsius. Where only one temperature is given within the parentheses, the density in grams per milliliter at the indicated temperature is shown instead of the specific gravity.

c) Compound is persistent in that medium

8.3.1.2 Water Solubility

Water solubility is the maximum concentration of a chemical that dissolves in pure water at a specific temperature and pH. Solubility of an inorganic species can vary widely, depending on temperature, pH, Eh (redox potential), and the types and concentrations of complexing species present. Solubilities range from less than 1 ppb to greater than 100,000 ppm. Water solubility is a critical property affecting environmental fate. Highly soluble chemicals can be rapidly leached from wastes and contaminated soil and are generally mobile in groundwater. Solubility is one of the controlling factors affecting leachate strength and migration of chemicals from waste sites (along with sorption potential, soil type, and water infiltration). Soluble chemicals also tend to be more readily biodegradable than those with low solubility (Lyman, 1982a). Water solubility is especially important in the evaluation of aquatic exposure pathways. Solubility affects "leachability" into both groundwater and surface water, and highly soluble compounds are usually less strongly adsorbed (thus more mobile) in both groundwater and surface water. In general, high solubility is associated with lower volatilization rates (Menzer and Nelson, 1980).

8.3.1.3 Organic Carbon Partition Coefficient (Koc) and Octanol-Water Partition Coefficient (Kow)

The organic carbon partition coefficient (Koc) is a measure of relative sorption potential for organics and is a significant environmental fate determinant for all exposure pathways, especially aqueous pathways. The Koc indicates the tendency of an organic chemical to be adsorbed, and is largely independent of soil properties (Lyman, 1982b). Koc is expressed as the ratio of amount of chemical adsorbed per unit weight of organic carbon to the chemical concentration in solution at equilibrium. Therefore:

$$\text{Koc} = \frac{\text{mg adsorbed/kg organic carbon}}{\text{mg dissolved/liter solution}}$$

The significance and interpretation of Koc varies with different exposure pathways. For groundwater, low Koc values indicate faster leaching from the waste source into an aquifer and relatively rapid transport through the aquifer (i.e., limited retardation of the chemical). Therefore, among chemicals with similar indicator score (IS) values due to groundwater pathways, high mobility (low Koc) chemicals generally would be of more concern.

For surface water pathways, Koc also has several significant implications. Once a chemical gets into surface water, a high Koc may be of great concern because it indicates a tendency to bioaccumulate. If aquatic food chain pathways are possibly significant, this implication of Koc should be considered. The Koc value also indicates the relative amount of sediment adsorption in surface water.

The octanol-water partition coefficient (Kow) is a measure of a chemical's solubility in octanol and water at equilibrium. The Kow is used as an indication of a chemical's propensity for bioconcentration by aquatic organisms. For the convenience of the user, values for Kow are expressed as log Kow in Table 8-6.

8.3.1.4 Advection and Dispersion

Advection is the passive movement of solutes along with the general flow of groundwater. Therefore, the faster the groundwater flows, the further a contaminant will be transported from its source.

Dispersion is the movement of solutes within a body of water. This movement is influenced by molecular diffusion and mechanical mixing. Although dispersion contributes to the dilution of a contaminant, it can also increase the area that will be affected.

8.3.1.5 Hydrolysis and Oxidation

Hydrolysis and oxidation are the primary chemical reactions expected for organic compounds in groundwater. Hydrolysis is the decomposition of a compound by reaction with water. Oxidation is the transformation of a compound by the loss of electrons. Chlorinated hydrocarbons and aromatics do not readily enter into these reactions unless there are elevated temperatures or significant changes in pH from neutral; thus, these indicator organic chemicals are not expected to be changed at the Ciba-Geigy Site.

8.3.1.6 Degradation

Degradation is the breakdown of organic compounds into one or more simpler compounds. Contaminant concentration, temperature, pH, and the types of organisms present will determine the extent of chemical degradation and biodegradation and the products formed. With regard to biodegradation a contaminant must be present at parts per million concentrations in order to be metabolized to any extent by microorganisms. Degradation of the organic indicator chemicals at the Ciba-Geigy Site is not expected to be an important process.

8.3.1.7 Half-Life

Chemical half-lives are measures of a chemical's persistence in various environmental media; that is, in any given half-life, one-half of the initial concentration of the chemical will be removed. Table 8-6 presents values for overall half-lives in various media. These values are based on all removal mechanisms acting together rather than on a single removal mechanism.

8.3.2 Organic Indicator Chemicals

Section 8.3.2 briefly summarizes specific environmental fate and transport mechanisms for each of the organic indicator chemicals.

8.3.2.1 Benzene

Volatilization appears to be the major transport process of benzene from surface waters to the ambient air, and atmospheric transport of benzene occurs readily (EPA, 1979). Although direct oxidation of benzene in environmental waters is unlikely, cloud chamber data indicate that it may be photooxidized rapidly in the atmosphere. Since volatilization is likely to be the main transport process accounting for the removal of benzene from water, the atmospheric destruction of benzene is probably the most likely fate process. Values for benzene's log octanol/water partition coefficient (Kow) indicate that adsorption onto organic material may be significant under conditions of constant exposure. Sorption processes are likely removal mechanisms in both surface water and groundwater. Although the bioaccumulation potential for benzene appears to be low, gradual biodegradation by a variety of microorganisms probably occurs. The rate of benzene biodegradation may be enhanced by the presence of other hydrocarbons.

8.3.2.2 Chlorobenzene

The primary mechanism of transport from surface water for chlorobenzene is volatilization, although adsorption and bioaccumulation may also be factors. Chlorobenzene would be expected to move slowly in soil because of its high Kow and consequent adsorption to soil organic material. Additional information can be obtained for chlorobenzene in the Ambient Water Quality Criteria for Chlorinated Benzenes, (EPA, 1980).

8.3.2.3 Chloroform

Volatilization into the atmosphere is the major transport process for removal of chloroform from aquatic systems (EPA, 1979). Once in the troposphere, chloroform is attacked by hydroxyl radicals with the subsequent formation of phosgene ($COCl_2$) and possibly chlorine oxide (ClO) radicals. Neither of these reaction products is likely to persist; phosgene is readily hydrolyzed to hydrochloric acid and carbon dioxide. Reaction with hydroxy radicals is thought to be the primary enviornmental fate of chloroform. However, chloroform that remains in the troposphere may return to earth in precipitation or adsorbed on particulates, and a small amount may diffuse upward to the stratosphere where it photodissociates via interaction with ultraviolet light.

Photolysis, hydrolysis, and sorption do not appear to be significant environmental fate processes for chloroform. However, sorption processes may have some importance as a removal mechanism in groundwater and soil. The Kow indicates that this compound may bioaccumulate under conditions of constant exposure. Studies with marine organisms provide evidence for only weak to moderate bioaccumulation. Although chloroform is somewhat lipophilic and tends to be found at higher concentrations in fatty tissues, there is no evidence for biomagnification in aquatic food chains.

8.3.2.4 1,2-Dichloroethane

The primary method of transport from surface water for 1,2-dichloroethane is volatilization. In the atmosphere, 1,2-dichloroethane is rapidly broken down by hydroxylation, although some may be absorbed by atmospheric water and returned to the earth by precipitation. No studies on the adsorption of 1,2-dichloroethane onto soil were reported in the literature examined. However, 1,2-dichloroethane has a low Kow and is slightly soluble in water; therefore, leaching through the soil into the groundwater is an expected route of transport.

8.3.2.5 Tetrachloroethene

Tetrachloroethene (PCE) rapidly volatilizes into the atmosphere where it reacts with hydroxyl radicals to produce HCl, CO, CO_2, and carboxylic acid. This is probably the most important transport and fate process for PCE in the environment. PCE will leach into the groundwater, especially in soils of low organic content. In soils with high levels of organics, PCE adsorbs to these materials and can be bioaccumulated to some degree. However, it is unclear if PCE bound to organic material can be degraded by microorganisms or must be desorbed to be destroyed. There is some evidence that higher organisms can metabolize PCE.

8.3.2.6 1,2,4-Trichlorobenzene

There is little information available concerning the environmental fate and transport of 1,2,4-trichlorobenzene (1,2,4-TCB). Although there is no information on the sorption of 1,2,4-TCB to soils and sediments, the high Kow suggests that this compound would be adsorbed to organic materials in soil and sediment. The volatility of 1,2,4-TCB is relatively low, but it has been found to volatilize readily from aerated and quiescent waters; thus, air transport is likely. Sorption to suspended solids, however, does reduce the rate of volatilization (EPA, 1985).

1,2,4-TCB has been shown to oxidize in the atmosphere via attack by hydroxyl radicals. It is not known if the compound is broken down through photolysis or hydrolysis. Biodegradation of 1,2,4-TCB has been shown to occur in waste treatment studies; however, environmental biodegradation is expected to be slower (EPA, 1985).

8.3.2.7 Trichloroethene

Trichloroethene (TCE) rapidly volatilizes into the atmosphere where it reacts with hydroxyl radicals to produce hydrochloric acid, carbon monoxide, carbon dioxide, and carboxylic acid. This is probably the most important transport and fate process for trichlorothene in surface water and in the upper layers of soil. TCE adsorbs to organic materials and can be bioaccumulated to some degree. However, it is unclear whether TCE bound to organic material can be degraded by microorganisms or must be desorbed to be destroyed. There is some evidence that higher organisms can metabolize TCE. It leaches into the groundwater fairly readily, and it is a common contaminant of groundwater.

8.3.3 Inorganic Indicator Chemicals

Section 8.3.3 briefly summarizes specific environmental fate and transport mechanisms for each of the inorganic indicator chemicals.

8.3.3.1 Arsenic

In the natural environment, arsenic has been found in different oxidation states. Interconversions of the +3 and +5 states, as well as organic complexation, are the most important chemical reactions which determine arsenic's distribution and mobility. In the aquatic environment, biological activity or highly reducing conditions produce volatile arsine or methylarsenics, thus increasing arsenic's mobility in the environment. Because of its general mobility, arsenic tends to cycle through the environment. Sorption by the sediment may also be an important fate for the chemical.

8.3.3.2 Barium

Barium is an alkaline-earth metal which is extremely reactive and readily forms insoluble carbonate and sulfate salts. Barium is generally present in solution in surface water or groundwater only in trace amounts. Large amounts will not dissolve because natural waters usually contain sulfate, and the solubility of barium sulfate is generally low. Barium is not soluble at more than a few parts per million in water that contains sulfate at more than a few parts per million. However, barium sulfate may become considerably more soluble in the presence of chloride and other anions. The soluble form of barium in most aquatic systems may be controlled by the solubility product of barium carbonate. In the absence of any other possible removal mechanisms, the residence time of barium in aquatic systems could be several hundred years. Atmospheric transport of barium, in the form of particulates, can occur. Bioaccumulation is not an important process for barium. In soils, barium is not expected to be very mobile because of its formation of water-insoluble salts and its inability to form soluble complexes with humic and fulvic materials. Under acidic conditions, however, some of the water-insoluble barium compounds may be solubilized and move back into groundwater.

8.3.3.3 Cadmium

Cadmium is a metal that can be present in many chemical forms in wastes or in the environment. Some forms are insoluble in water, however, cadmium is relatively mobile in the aquatic environment. Cadmium is removed from aqueous media by complexing with organic materials and subsequently being adsorbed to the sediment. Cadmium appears to move slowly through soil and is not significantly depleted from soil through uptake by plants.

8.3.3.4 Nickel

Nickel is a highly mobile metal in aquatic systems because many nickel compounds are highly soluble in water. However, the insoluble sulfide is formed under reducing conditions and in the presence of sulfur. Above pH 9, precipitation of the hydroxide or carbonate exerts some control on nickel mobility. In aerobic environments below pH 9, soluble compounds are formed with hydroxide, carbonate, sulfate, and organic ligands.

In general, nickel is not accumulated in significant amounts by aquatic organisms. Bioconcentration factors are usually on the order of 100 to 1,000. Uptake of nickel from the soil by plants can also occur. Photolysis, volatilization, and biotransformation are not important environmental fate processes for nickel.

8.4 Toxicity Assessments

The following section presents toxicity profiles and regulatory information for each indicator chemical. Terms relevant to the toxicity profiles are presented, followed by the organic and inorganic indicator chemical toxicity assessments. Unless otherwise noted, these discussions are a summary of the available data (EPA, 1984; EPA, 1985). Regulatory guidance is also briefly summarized for each indicator chemical as provided in a number of sources (EPA, 1980; EPA, 1985). Where available, maximum contaminant levels (MCL) and ambient water quality criteria (AWQC) are presented. Table 8-7 presents a summary of the toxicity information for each indicator chemical.

TABLE 8-7

TOXICITY INFORMATION FOR THE INDICATOR CHEMICALS(a)

		CARCINOGENS		NONCARCINOGENS						Health Goals and Standards		
		CPF		RVe		Oral		Inhalation				
Chemical	EPA Weight-of-Evidence Category	Oral (mg/kg/d)-1	Inhalation (mg/kg/d)-1	Oral Route	Inhalation Route	AIS (mg/kg/d)	AIC (mg/kg/d)	AIS (mg/kg/d)	AIC (mg/kg/d)	MCL (mg/L)	RMCL (mg/L)	AWQC (b) (mg/L)
Arsenic	A	1.50E+01	5.00E+01	9	9	NL(c)	NL	NL	NL	0.05	NL	0 (2.2 ng/L)
Barium (d)	D	NL	NL	10	10	NL	5.10E-02	1.40E-03	1.40E-04	1.0	NL	NL
Benzene	A	5.20E-02	2.60E-02	5	10	NL	NL	NL	NL	0.005	0	0 (0.6 ug/L)
Cadmium	B1	NL	6.10E+00	10	8	NL	2.90E-04	NL	NL	0.010	NL	0.010
Chlorobenzene (d)	D	NL	NL	4	1	2.70E-01	2.70E-02	5.30E-02	5.70E-03	NL	0.06	0.49
Chloroform	B2	8.10E-02	NL	NL	NL	NL	1.00E-02	NL	NL	NL	NL	0
1,2-Dichloroethane	B2	9.10E-02	3.50E-02	10	8	NL	NL	NL	NL	0.005	0	0 (0.94 ug/L)
Nickel	A	NL	1.19E+00	10	10	2.00E-02	1.00E-02	NL	NL	NL	NL	0.013
Tetrachloroethene	B2	5.10E-02	1.70E-03	7	10	NL	2.00E-02	NL	NL	NL	NL	0 (0.8 ug/L)
1,2,4-Trichlorobenzene	NL	NL	NL	4	1	NL	2.00E-02	NL	NL	NL	NL	NL
Trichloroethene	B2	1.10E-02	4.60E-03	5	4	NL	NL	NL	NL	0.005	NL	0 (2.7 ug/L)

NOTES:

(a) All values from EPA, 1986.

(b) For suspect or proven carcinogens, concentrations associated with a range of incremental cancer risks are provided in parentheses to supplement a criterion of zero.

(c) Not listed in EPA, 1986 or IRIS, 1986.

(d) Weight-of-evidence value from EPA, 1984.

8.4.1 Definition of Terms

A number of terms commonly used in toxicity assessments for carcinogenic and noncarcinogenic effects are defined below.

8.4.1.1 Severity of Effect Ratings

Severity of effect ratings (RVe) are rating constants that are unitless integers ranging from 1 to 10, corresponding to various levels of severity of noncarcinogenic effects. Table 8-8 lists the RVes for noncarcinogens (EPA, 1986).

8.4.1.2 Acceptable Intake for Subchronic Exposure

The acceptable intake for subchronic exposure (AIS) is the highest human intake of a chemical, expressed as mg/kg/day, that does not cause adverse effects when exposure is short-term. The AIS is usually based on subchronic animal studies. AIS values are short-term acceptable intake levels.

8.4.1.3 Acceptable Intake for Chronic Exposure

The acceptable intake for chronic exposure (AIC) is the highest human intake of a chemical, expressed as mg/kg/day, that does not cause adverse effects when exposure is long-term (lifetime). The AIC is usually based on chronic animal studies. AIC values are long-term acceptable intake levels.

8.4.1.4 Chronic Hazard Index

The chronic hazard index (CHI) is a ratio of the lifetime average daily exposure of a chemical contaminant to the acceptable intake exposure level. If this ratio is greater than 1, then the lifetime average daily exposure has exceeded the acceptable intake exposure level, indicating that a potential health hazard exists.

TABLE 8-8
RATING CONSTANTS (RVe) FOR NONCARCINOGENS[(a)]

Effect (in animals)	Severity Rating (RVe)
Enzyme induction or other biochemical change with no pathologic changes and no change in organ weights.	1
Enzyme induction and subcellular proliferation or other changes in organelles, but no other apparent effects.	2
Hyperplasia, hypertrophy, or atrophy, but no change in organ weights.	3
Hyperplasia, hypertrophy, or atrophy, with changes in organ weights.	4
Reversible cellular changes: cloudy swelling, hydropic change, or fatty changes.	5
Necrosis or metaplasia, with no apparent decrement of organ function. Any neuropathy without apparent behavioral, sensory, or physiologic changes.	6
Necrosis, atrophy, hypertrophy, or metaplasia, with a detectable decrement of organ functions. Any neuropathy with a measurable change in behavioral, sensory, or physiologic activity.	7
Necrosis, atrophy, hypertrophy, or metaplasia, with definitive organ dysfunction. Any neuropathy with gross changes in behavior, sensory, or motor performance. Any decrease in reproductive capacity, any evidence of fetotoxicity.	8
Pronounced pathologic changes with severe organ dysfunction. Any neuropathy with loss of behavioral or motor control or loss of sensory ability. Reproductive dysfunction. Any teratogenic effect with maternal toxicity.	9
Death or pronounced life-shortening. Any teratogenic effect without signs of maternal toxicity.	10

(a) (EPA, 1986)

8.4.1.5 Weight-of-Evidence Ratings

The weight-of-evidence categories for potential carcinogens qualify the level of evidence that supports designating a chemical as a human carcinogen. Table 8-9 presents the weight-of-evidence categories for potential carcinogens (EPA, 1986).

8.4.1.6 Carcinogenic Potency Factor

The carcinogenic potency factor (CPF) is used for estimating the lifetime (70 years) probability of a human contracting cancer caused by exposure to known or suspected human carcinogens. This factor is the slope of the cancer risk dose-response curve and is generally reported in $(mg/kg/d)^{-1}$. This slope is determined through an assumed low-dosage linear relationship and extrapolation from high to low dose responses determined from animal studies. The value used in reporting the slope factor is an upper 95 percent confidence limit on the probability of response per unit intake of a chemical over a lifetime, converting estimated intakes directly to incremental risk.

8.4.1.7 Risk

Risk is the expected frequency of undesirable effects arising from exposure to a pollutant (WHO, 1978). A cancer risk of 10^{-6} is the risk of one additional case of cancer per 1 million people in an exposed population of 200 million.

8.4.1.8 Ambient Water Quality Criteria

The ambient water quality criteria (AWQC) are health-based estimates of the ambient surface water concentration that will not result in adverse health effects in humans and are not enforceable regulatory guidelines. AWQCs consider acute and chronic effects in both freshwater and saltwater aquatic life. Also considered are adverse carcinogenic and noncarcinogenic health effects in humans from ingestion of both water (2 liters/day) and aquatic organisms (6.5 grams/day) and from ingestion of water alone (2 liters/day). The AWQCs for protection of human health for carcinogenic substances are based on the specified incremental cancer risk of 10^{-6}.

TABLE 8-9
WEIGHT-OF-EVIDENCE CATEGORIES FOR POTENTIAL CARCINOGENS[a]

EPA Category	Description of Group	Description of Evidence
Group A	Human Carcinogen	Sufficient evidence from epidemiologic studies to support a causal association between exposure and cancer
Group B1	Probable Human Carcinogen	Limited evidence of carcinogenicity in humans from epidemiologic studies
Group B2	Probable Human Carcinogen	Sufficient evidence of carcinogenicity in animals, inadequate evidence of carcinogenicity in humans
Group C	Possible Human Carcinogen	Limited evidence of carcinogenicity in animals
Group D	Not Classified	Inadequate evidence of carcinogenicity in animals
Group E	No Evidence of Carcinogenicity in Humans	No evidence of carcinogenicity in at least two adequate animal tests or in both epidemiologic and animal studies

---

(a) (EPA, 1986)

8.4.1.9 Recommended Maximum Contaminant Levels

Recommended maximum contaminant levels (RMCLs) are nonenforceable health goals for drinking water which are to be set at levels that would result in no known or anticipated adverse health effects with an adequate margin of safety. RMCLs for substances considered to be probable human carcinogens are set at zero, and RMCLs for substances not treated as probable carcinogens are based upon chronic toxicity or other data (EPA, 1985a).

8.4.1.10 Maximum Contaminant Levels

Maximum contaminant levels (MCLs) are enforceable standards for drinking water and are set as close to the RMCLs as is feasible. MCLs are based upon treatment technologies, cost (affordability), and other feasibility factors, such as availability of analytical methods, treatment technology, and costs for achieving various levels of removal (EPA, 1985a). An MCL for a toxic chemical represents the allowable lifetime exposure to the contaminant for a 70-kg adult who is assumed to ingest 2 liters of water per day (EPA, 1986).

8.4.2 Organic Indicator Chemical Toxicity Assessments

Section 8.4.2 provides toxicity assessments for each of the organic indicator chemicals.

8.4.2.1 Benzene

Toxicity Profile: Benzene is categorized as a Group A - Human Carcinogen. The noncarcinogenic RVe designates benzene as a 5 for the oral route of exposure and 10 for the inhalation route of exposure.

Chronic inhalation studies in humans are represented by several epidemiologic reports on benzene exposure in the work place that showed a significant increase in the incidence of leukemia among workers occupationally exposed to benzene. Animal data concerning the carcinogenicity of inhaled benzene are equivocal (EPA, 1984).

The primary target of benzene toxicity is in red blood cell production and is believed to cause pancytopenia, a reduction in the number of all types of circulating blood cells. In an oral study with female rats dosed with benzene at 1, 10, 50, or 100 mg/kg benzene in olive oil, 5 days/week for 187 days, adverse hematopoietic effects were seen at all dose levels except the lowest (EPA, 1984).

Studies on the effects of benzene exposure on fetuses have had conflicting results. An oral study showed no significant fetotoxic effects in mice at 0.3, 0.5, or 1 mg/kg/day administered on days 6 through 15 of gestation. Similarly, another study showed no treatment-related effects in the litters of rabbits exposed to 500 ppm, 7 hours/day, on days 6 through 18 of gestation. However, an inhalation study with rats produced fetotoxic effects at 50 ppm and 500 ppm, but none at 10 ppm (EPA, 1984).

Regulatory Requirements, Standards, and Criteria: An MCL of 0.005 mg/L and an RMCL of zero have been established for benzene. The AWQC for the protection of human health from the potential carcinogenic effects due to exposure to benzene through ingestion of contaminated water and aquatic organisms is zero. The CPFs for the oral and inhalation routes of exposure to benzene are 5.20×10^{-2} and 2.60×10^{-2} $(\mathrm{mg/kg/d})^{-1}$, respectively. Since benzene is a carcinogen, no AIS and/or AIC values have been determined.

8.4.2.2 Chlorobenzene

Toxicity Profile: Chlorobenzene is categorized as a Group D chemical - Not Classified. The noncarcinogenic RVe designates chlorobenzene as a 4 for the oral route of exposure and as a 1 for the inhalation route of exposure.

Animal studies with rats and dogs have shown the liver and kidneys to be the target organs of chlorobenzene toxicity. Several subchronic oral studies with rats have shown that chlorobenzene exposure resulted in increased liver and kidney weights. Two studies showed no observed effects at levels of 27.3 mg/kg/day in dogs and 50 mg/kg/day in rats after oral dosing for 90 to 99 days. The highest dose in dogs (272.5 mg/kg/day) produced histopathological changes in the liver, kidneys, and spleen. The highest dose in rats (250 mg/kg/day) led to increased liver and kidney weights (EPA, 1984).

There was insufficient evidence in the literature reviewed to draw conclusions on the fetotoxic or carcinogenic potential of chlorobenzene exposure.

Regulatory Requirements, Standards, and Criteria: No MCL for chlorobenzene has been established; however, the RMCL is 0.06 mg/L. The AWQC for the protection of human health from the toxic effects due to exposure to chlorobenzene through the ingestion of contaminated water and aquatic organisms is 0.49 mg/L.

The AIS and AIC values determined for the oral route of chlorobenzene are 2.70×10^{-1} and 2.70×10^{-2} mg/kg/day, respectively. The AIS and AIC values determined for the inhalation route are 5.30×10^{-2} and 5.70×10^{-3} mg/kg/day, respectively.

8.4.2.3 Chloroform

Toxicity Profile: Chloroform is categorized as a Group B2 - Probable Human Carcinogen. Noncarcinogenic severity ratings (RVes) were not provided for the oral and inhalation routes of exposure.

Acute exposure to high concentrations of chloroform in animals has led to central nervous system (CNS) depression. In addition to its CNS effects, chloroform has been associated with toxic effects in the liver and kidney. An inhalation study resulted in cloudy swelling of the kidneys and tissue damage of the liver in rats exposed to 50 and 85 ppm, 7 hours/day, 4 days/week for 6 months (EPA, 1985).

Chronic oral studies have focused on the carcinogenic effects of chloroform. Rats and mice were administered various concentrations of chloroform orally. Male rats developed surface kidney tumors at 90 and 180 mg/kg/day. Male mice developed liver cell carcinomas at 138 and 277 mg/kg/day, whereas female mice developed similar carcinomas at 238 and 477 mg/kg/day (EPA, 1985).

Regulatory Requirements, Standards, and Criteria: No MCL or RMCL has been established for chloroform. The AWQC for the protection of human health from the potential carcinogenic effects due to exposure to chloroform through ingestion of contaminated water and aquatic organisms is zero. The CPF for the oral route of exposure to chloroform is 8.10×10^{-2} $(mg/kg/d)^{-1}$. The oral AIC has been established as 1.00×10^{-2} mg/kg/day.

8.4.2.4 1,2-Dichloroethane

Toxicity Profile: 1,2-Dichloroethane has been categorized as a Group B2 -Probable Human Carcinogen. The noncarcinogenic RVe designates 1,2-dichloroethane as a 10 for the oral route of exposure and as an 8 for the inhalation route of exposure.

Chronic studies involving oral exposures of rats and mice to 1,2-dichloroethane produced a variety of tumors, including tumors of the blood vessels, lung, mammary glands, and uterus. 1,2-Dichloroethane has also been found to be mutagenic when tested using bacterial test systems, whereas fetotoxic effects have not been determined (EPA, 1985).

Acute oral and inhalation exposure in humans has been shown to cause central nervous system depression and gastrointestinal disturbances such as headache, dizziness, nausea, vomiting, abdominal pain, irritation of the mucous membranes, and liver and kidney dysfunction. In severe cases, leukocytosis may be diagnosed, and internal hemorrhaging and pulmonary edema leading to death may occur. Similar effects were observed in experimental animals (EPA, 1985).

Regulatory Requirements, Standards, and Criteria: No MCL for 1,2-dichloroethane has been established; however, an RMCL of zero has been determined. The AWQC for the protection of human health from the potential carcinogenic effects due to exposure to 1,2-dichloroethane through ingestion of contaminated water and aquatic organisms is zero. The CPFs for the oral and inhalation routes of exposure for 1,2-dichloroethane are 9.10×10^{-2} and 3.50×10^{-2} $(mg/kg/d)^{-1}$, respectively. No AIS and/or AIC values have been established.

8.4.2.5 Tetrachloroethene

Toxicity Profile: Tetrachloroethene (PCE) has been classified as a Group B2 - Probable Human Carcinogen. The noncarcinogenic RVe designates tetrachloroethene as a 7 for the oral route of exposure and a 10 for the inhalation route of exposure.

Tetrachloroethene, when administered orally in mice, was found to produce liver cancer in both males and females. Elevated mutagenic activity was found in bacterial assays treated with PCE. Bone formation was altered in the offspring of pregnant mice exposed to 2000 mg/m^3 of PCE for 7 hrs/day on days 6 through 15 of gestation (EPA, 1985). Subchronic inhalation studies showed liver and kidney damage in albino rats and guinea pigs at 200 to 400 ppm PCE; however, no adverse effects were seen in rabbits or monkeys.

The effects of PCE inhalation on fetuses were demonstrated in mice; however, data for human teratogenic effects have not been found. The carcinogenic potential of PCE was evaluated by the increased incidence of liver cell carcinoma in mice and the increased incidence of death due to carcinomas in laundry workers exposed to PCE (HEA, PCE, 1984).

Regulatory Requirements, Standards, and Criteria: No MCL or RMCL has been established for PCE. The AWQC for the protection of human health from the potential carcinogenic effects due to exposure to PCE through ingestion of contaminated water and aquatic organisms is zero. The CPFs for the oral and inhalation routes of exposure to PCE are 5.10×10^{-2} and 1.70×10^{-3} $(mg/kg/d)^{-1}$, respectively. The AIC value for the oral route of exposure is 2.00×10^{-2} mg/kg/day.

8.4.2.6 1,2,4-Trichlorobenzene

Toxicity Profile: 1,2,4-Trichlorobenzene (1,2,4-TCB) is not classified as a carcinogen. The noncarcinogenic RVe designates 1,2,4-TCB as a 4 for the oral route of exposure and a 1 for the inhalation route of exposure.

The toxic effects of exposure to trichlorobenzene (TCB) have not been well defined. There are no reports indicating carcinogenic, teratogenic, or mutagenic activity of TCB in humans or animals. No specific reproductive effects have been found for TCBs, but embryo toxicity has been observed at dose levels that also produced material toxicity in rats (Kitchin & Ebron, 1983).

Several animal studies on the subchronic toxicity of TCB have been reported. Inhalation studies have not shown major irreversible effects, although some effects on liver and kidney were found (histological changes, increased liver weight).

Regulatory Requirements, Standards, and Criteria: No MCL or RMCL has been established for 1,2,4-TCB. Due to insufficent data, an AWQC for the protection of human health has not been determined. An AIC value for the oral route of exposure to 1,2,4-TCB is 2.00×10^{-2} mg/kg/day, while the AIC value for the inhalation route of exposure has not been determined. However, the U.S. EPA has proposed an ADI of 0.02 mg/kg/day based on the subchronic NOAEL (no-observed-adverse-effect level) of 20 mg/kg/day found in the oral, 90-day Carlson and Tardiff rat study (1976), and the application of the 1000-fold safety factor for a subchronic animal study.

8.4.2.7 Trichloroethene

Toxicity Profile: Trichloroethene (TCE) is categorized as a Group B2 - Probable Human Carcinogen. The noncarcinogenic RVe designates TCE as a 5 for the oral route of exposure and a 4 for the inhalation route of exposure.

The National Toxicology Program studied the carcinogenic effects of TCE in Fisher 344 rats at 500 mg/kg or 1000 mg/kg, 5 days/week, for 103 weeks. Higher dosed males showed an increase in kidney carcinomas, and a number died of kidney failure (EPA, 1984). Oral administration of TCE to mice results in liver cancers. It was found to be mutagenic by means of microbial assay systems but does not appear to cause reproductive or teratogenic toxicity (EPA, 1985).

Regulatory Requirements, Standards, and Criteria: No MCL has been determined, but an RMCL has been established for TCE as zero. AWQC for the protection of human health from the potential carcinogenic effects due to exposure to TCE through ingestion of contaminated water and aquatic organisms is zero. The CPF values for the oral and inhalation routes of exposure to TCE are $1.10\text{x}10^{-2}$ and $4.60\text{x}10^{-3}$ $(\text{mg/kg/d})^{-1}$, respectively. No AIS or AIC values have been determined.

8.4.3 Inorganic Indicator Chemical Toxicity Assessments

Section 8.4.3 provides toxicity assessments for each of the inorganic indicator chemicals.

8.4.3.1 Arsenic

Toxicity Profile: Arsenic is classified as a Group A - Human Carcinogen. The noncarcinogenic RVe designates arsenic as a 9 for both the oral and inhalation routes of exposure.

Arsenic, particularly the trivalent inorganic form, has been associated with the occurrence of lung and skin cancers in humans. Evidence of the carcinogenic effect of arsenic in humans was shown in an investigation that followed 74 patients who used an antiasthmatic at an estimated 2.5 mg As/day (as arsenic trioxide) or 10.3 mg As/day (as arsenic sulfide) for periods ranging from 6 months to 15 years. Five percent of the patients developed internal malignancies including squamous cell carcinomas of the lung and gall bladder and one hemangiosarcoma of the liver (EPA, 1984).

Subchronic and chronic studies have shown the targets of arsenic toxicity to be the skin, lungs, peripheral nervous system, peripheral vascular system, gastrointestinal tract, and kidneys. Rats have proved to be more susceptible than guinea pigs, cats, dogs, or man (EPA, 1984).

Regulatory Requirements, Standards, and Criteria: The MCL for arsenic in drinking water is 0.05 mg/L; however, no RMCL has been established. The AWQC for the protection of human health from the potential carcinogenic effects due to exposure to arsenic through ingestion of contaminated water and aquatic organisms is zero.

The CPFs for the oral and inhalation routes of exposure to arsenic are 1.50×10^{1} and 5.00×10^{1} $(\text{mg/kg/day})^{-1}$, respectively. Since arsenic has been determined to be carcinogenic to humans, no AIS or AIC have been determined.

8.4.3.2 Barium

Toxicity Profile: Barium is classified as a Group D chemical - Not Classified. The noncarcinogenic RVe designates barium as a 10 for both the oral and inhalation routes of exposure.

Barium exerts its toxic effect by replacing calcium in a number of calcium-mediated activities. There are reports that barium exposure can lead to an increase in muscle excitability, primarily in the human cardiac muscle. An Illinois study showed an increase in cardiovascular disease where a community consumed water containing 7 mg/L of Ba, but no effect in a community where the Ba level was 0.1 mg/L (EPA, 1984).

Regulatory Requirements, Standards, and Criteria: An MCL of 1.0 mg/L has been established for Ba in drinking water; however, an RMCL has not been determined. Oral and inhalation AICs have been established as 5.10×10^{-2} and 1.40×10^{-4} mg/kg/day, respectively.

8.4.3.3 Cadmium

Toxicity Profile: Cadmium is categorized as a Group B1 - Probable Human Carcinogen. The noncarcinogenic RVe designates cadmium as a 10 for the oral route of exposure and 8 for the inhalation route of exposure.

Animal studies have shown that cadmium exposure by inhalation caused lung tumors in rats, and exposure by injection produced injection-site tumors. An increased incidence of tumors has not been seen in animals exposed to cadmium orally (EPA, 1985).

Cadmium is a known animal teratogen and reproductive toxin. It has been shown to cause kidney dysfunction in both humans and animals. Other toxic effects attributed to cadmium include immunosupression (in animals), anemia (in humans), pulmonary disease (in humans), possible effects on the endocrine system, defects in sensory function, and bone damage (EPA, 1985).

Regulatory Requirements, Standards, and Criteria: An MCL of 0.010 mg/L has been established for cadmium. The AWQC for the protection of human health from the toxic effects due to the exposure to cadmium through ingestion of contaminated water and aquatic organisms is 0.010 mg/L. The CPF for the inhalation route of exposure to cadmium is 6.10×10^{0} (mg/kg/day)-1. The AIC value for the oral route of exposure if 2.90×10^{-4} mg/kg/day.

8.4.3.4 Nickel

Toxicity Profile: Nickel is categorized as a Group A - Human Carcinogen for the inhalation route of exposure. The noncarcinogenic RVe designates nickel as a 10 for both oral and inhalation routes of exposure.

There is extensive epidemiological evidence indicating excess cancer of the lung and nasal cavity for workers at nickel refineries and smelters, and weaker epidemiological evidence for excess risk in workers at nickel electroplating and polishing operations. Respiratory tract cancers have occurred in excess at industrial facilities that are metallurgically diverse in their operations. The nickel compounds that have been implicated as having carcinogenic potential are insoluble dusts of nickel subsulfide and nickel oxides, the vapor of nickel carbonyl, and soluble aerosols of nickel sulfate, nitrate, or chloride. Inhalation studies with experimental animals suggest that nickel subsulfide and nickel carbonyl are carcinogenic in rats (EPA, 1985).

Several nickel compounds are mutagenic and can cause chromosomal alterations. Information was not available for assessing teratogenic and reproductive effects of nickel in humans and experimental animals (EPA, 1985).

Dermatitis and other dermatological effects are the most frequent effects of exposure to nickel and nickel-containing compounds. The dermatitis is a sensitization reaction of the skin. Most information regarding acute toxicity of nickel involves inhalation exposure to nickel carbonyl. Studies with experimental animals suggest that nickel and nickel compounds have relatively low acute and chronic oral toxicity (EPA, 1985).

Regulatory Requirements, Standards, and Criteria: No MCL or RMCL values have been determined for nickel. The AWQC for the protection of human health from the toxic properties of nickel ingested through contaminated water and aquatic organisms is 0.013 mg/L. The CPF for the inhalation route of exposure to nickel is 1.19 $(mg/kg/d)^{-1}$. The AIS and AIC values established for the oral route of exposure are $2.00x10^{-2}$ and $1.00x10^{-2}$ mg/kg/day, respectively.

8.5 Human Exposure Routes

This section describes the human exposure routes that were evaluated for the baseline assessments. These assessments include the areas where the public is currently being exposed to migrating contaminants from the Ciba-Geigy Site. The human exposure routes include ingestion, dermal absorption, and inhalation..

A route of human exposure to chemicals found off of the Ciba-Geigy Site is through the ingestion route. Exposure to contaminants may result from the inadvertent ingestion of contaminated sediment or water.

A route of human exposure to chemicals found off of the Ciba-Geigy Site is through a dermal route of exposure. In order to be exposed, these chemicals found either in sediment or water, must come into direct contact with the body. To determine a dermal exposure, it is assumed that contaminants are carried through the skin as a solute in water which is adsorbed (rather than being preferentially adsorbed independently of the water) and that the contaminant concentration in the water being adsorbed is equal to the groundwater concentration of the contaminant (EPA, 1986a).

A route of human exposure to chemicals volatilizing from the Ciba-Geigy Site is through inhalation. These chemicals can be inhaled after volatilizing from off-site surface water and groundwater. Possible human exposures can result from residential uses of contaminated groundwater or from recreational uses of the marshland.

8.6 Baseline Completed Human Exposure Pathways

A completed baseline human exposure pathway is the mechanism by which a population or individual is currently being exposed to contaminants originating from a site. These pathways consist of four necessary elements: (1) a source and mechanism of chemical release; (2) an environmental transport medium (e.g., groundwater, surface water, soil, or air); (3) a potential human exposure point; and (4) a likely route of human exposure. Since each indicator chemical has specific chemical and physical characteristics, the exposure scenarios presented do not apply for every indicator chemical.

The data obtained on the five media analyzed (groundwater, surface water, soil sediments, and air), during the RI for the Ciba-Geigy Site showed that groundwater, marshland sediment, and marshland air can result in completed baseline human exposure pathways. These three media present both the release and transport characteristics necessary for a completed baseline human exposure pathway. The completed baseline pathways for groundwater were divided into two identified uses, residential and recreational, while the completed baseline pathway for marshland sediment and air were only identified for recreational uses. Each use is further delineated by the routes of exposure.

8.6.1 Residential Use Completed Pathways of Exposure

The evaluation of the uses of groundwater in the vicinity of the Ciba-Geigy Site led to the identification of several residential wells. Investigation revealed that several of these wells were used for residential purposes such as drinking, bathing (shower and bath), and for other domestic activities, as well as, agricultural purposes such as watering lawns and gardens, and filling swimming pools. For the purpose of quantifying baseline potential carcinogenic risk and baseline chronic (noncarcinogenic) effects, it was assumed that only the residential uses of water occur and that they will continue to occur at the baseline levels.

8.6.1.1 Residential Use: Ingestion Route

The completed baseline residential use pathway of exposure to groundwater contaminants present in residential wells, will result in a ingestion exposure. This ingestion exposure is from drinking the contaminated water. The completed human ingestion route identified for the baseline residential use pathway is

- o Ingestion of water from a residential well

8.6.1.2 Residential Use: Dermal Absorption Route

The completed baseline residential use pathway of exposure to groundwater contaminants present in residential wells will result in dermal exposures when the contaminated water comes into direct contact with the body (by showering and domestic activities). The absorption of chemicals into the body is calculated based on a chemical's absorptivity and a flux rate of water through human skin (EPA, 1986a). For the dermal absorption pathway, only the organic chemcials are evaluated since ionic inorganic chemicals are not absorbed through intact skin. The completed human dermal absorption route identified for the baseline residential use pathway is

- o Dermal absorption of water from a residential well

8.6.1.3 Residential Use: Inhalation Route

The completed baseline residential use pathway of exposure to groundwater contaminants volatilizing from sprayed water from a residential well, will result in an inhalation exposure. For the inhalation route, only the organic indicator chemicals are evaluated since ionic inorganic chemicals will remain in the water. A completed human inhalation exposure pathway occurs when these organic compounds volatilize from water during showering and other domestic activities and are inhaled by the individual. The completed human inhalation route for the baseline residential use pathway is

- Inhalation exposure to contaminated air from residential water

8.6.2 Recreational Use Completed Pathways of Exposure

Evaluations of the data in the RI indicate that the sediment in the marshland is contaminated with chemicals emanating from the Ciba-Geigy Site, thus creating the baseline pathway for human recreational exposure by walking in the marshland area.

8.6.2.1 Recreational Use: Ingestion Route

The completed baseline recreational pathway to contaminants from sediment results in an ingestion exposure route. The completed human ingestion route identified for the recreational use pathway is

- Incidental ingestion of sediment in the marshland

8.6.2.2 Recreational Use: Dermal Absorption Route

The completed recreational pathway to contaminants from sediment results in a dermal exposure. Only organic indicator chemicals result in dermal absorpton since ionic inorganic indicator chemicals are not absorbed through intact skin. The completed human dermal route identified for the baseline recreational use pathway is

- Dermal absorption of contaminants from sediments in the marshland

8.6.2.3 Recreational Use: Inhalation Route

The completed recreational pathway to contaminants volatilizing from the marshland results in an inhalation exposure. Based on the analytical results of the RI, the inhalation of dust from the marshland is not a completed route of exposure. The organic chemicals are the only chemicals of concern for the inhalation route. The completed human inhalation route identified for the recreational use pathway is

- Inhalation exposure to contaminated air from the marshland

8.7 Quantitative Baseline Evaluation of Health Effects

The quantitative baseline evaluation of health effects is the mathematical process whereby human health risks and hazards are characterized for potential carcinogens and for noncarcinogenic effects by combining the exposure and toxicity information developed in Sections 8.4 to 8.6. The carcinogenic risk is expressed as a probability while the chronic hazard index is expressed as a ratio. The carcinogenic risk and chronic hazard index are calculated based on the current site conditions and reflect the health effects posed by the site as it exists today.

The quantitative baseline evaluation of health effects includes

- Determining the indicator chemical concentrations for each completed human exposure pathway.

- Quantifying the Carcinogenic Risk, and the Noncarcinogenic Effects (chronic hazard index).

8.7.1 Determination of Indicator Chemical Concentrations Available for Human Exposure

Health effects can not be quantified unless contaminant concentrations are available. Contaminant concentrations presented in Section 8.2.1 reflect the current site conditions. Section 8.3 reviewed environmental transport of the contaminants. Groundwater, marshland sediment, and marshland air were identified as the release/transport media that can result in completed human exposure pathways. Human exposure point concentrations of indicator chemicals were chosen from the highest groundwater and sediment concentrations found off site.

The groundwater and marshland sediment concentrations of indicator chemicals were determined by selecting the highest detected concentration in off-site groundwater wells and off-site marshland sediment sample locations. Table 8-10 provides the indicator chemical concentrations chosen, and the associated well number and sediment sample location. Table 8-11 provides the values for the air concentrations derived for the residential water scenario, as well as, the actual air concentrations sampled at the marshland.

8.7.1.1 Concentrations of Indicator Chemicals in Residential Well Water

The concentrations of indicator chemicals for residential well water were determined by using Table 8-10. From this table, the highest recorded or detected concentration of contaminants from an off-site well were used.

TABLE 8-10
INDICATOR CHEMICAL, WELL NUMBER, SEDIMENT SAMPLE LOCATION, AND CONCENTRATIONS USED FOR EXPOSURE POINT CALCULATIONS

Indicator Chemical	Well Number	Groundwater Concentration (mg/L)	Sediment Sample Location	Sediment Concentration (mg/kg)
Arsenic	RI03D	0.012	NA[a]	-----
Barium	RI13D	0.395	NA	-----
Benzene	RI15D	0.080	AS3	2.250
Cadmium	RI03S	0.345	NA	-----
Chlorobenzene	RI04D	2.170	AS3	4.837
Chloroform	RI07	0.251	AS2	3.625
1,2-Dichloroethane	RI15D	0.006	AS3	0.032
Nickel	RI03S	0.612	NA	-----
Tetrachloroethene	RI05D	0.150	AS3	4.782
1,2,4-Trichlorobenzene	RI05S	0.330	AS6	4.953
Trichloroethene	RI05D	0.099	AS3	0.525

NOTE:

(a) Not Analyzed

TABLE 8-11
AIR CONCENTRATIONS OF INDICATOR CHEMICALS

Indicator Chemical	Residential Water (Shower) ERP[(a)] mg/m^3	Marshland Air[(b)] mg/m^3
Arsenic[(c)]	------	------
Barium[(c)]	------	------
Benzene	6.94×10^{-6}	2.07×10^{-3}
Cadmium[(c)]	------	------
Chlorobenzene	1.53×10^{-4}	1.01×10^{-2}
Chloroform	1.39×10^{-5}	1.08×10^{-2}
1,2-Dichloroethane	6.94×10^{-7}	NA[(d)]
Nickel[(c)]	------	------
Tetrachloroethene	6.94×10^{-6}	8.10×10^{-3}
1,2,4-Trichlorobenzene	2.08×10^{-5}	NA
Trichloroethene	6.94×10^{-6}	3.98×10^{-2}

NOTES:

(a) Derived from the highest off-site groundwater well concentration.

(b) Actual air concentrations performed by Radian Inc., in August, 1986.

(c) Compound does not volatilize from soil or water.

(d) Not analyzed.

8.7.1.2 Concentrations of Indicator Chemicals in Air from Residential Well Water during Showering

In this scenario, a person is exposed to organic compounds volatilizing into the air from bathroom shower waters. To determine the rate of volatilization and corresponding concentration of indicator chemicals in air, it is assumed that the water is allowed to run for a total of 25 minutes; the water spray sustains suspension in the air for 1 second; and the volatilized chemicals occupy the volume of the bathroom, 12 m^3. The volatilized indicator chemical concentrations within the bathroom is also assumed to be uniform. The following relationship is used to determine the average contaminant concentration which a person may be exposed to while taking a shower.

$$ERP = \frac{(ERX)(t)}{V} \quad (0.5) \qquad (1)$$

Where: *ERP = average contaminant concentration in air, (mg/m^3)
ERX = rate of contaminant release from spray in the air, (mg/min)
t = the time the spray is in the air, (1 sec)
V = volume of bathroom, (12 m^3)

*Half the contaminant concentration in air is assumed to denote an average concentration by which a person can be exposed while showering.

The rate of contaminant release, ERX is determined by Equation 2:

$$(ERX) = Q\,(P_{AO} - P_{AB}) \qquad (2)$$

Where: Q = flow rate of water from shower, assumed to be 10 L/min
P_{AO} = initial contaminant concentration in a water drop, (mg/L)
P_{AB} = final contaminant concentration in a drop before it hits the floor, (mg/L)

The value of P_{AB} is determined graphically from Figure 8-1 assuming drops are in turbulent or "circular" motion. This graph (Bennett, 1974) shows a correlation between two dimensionless values defined in Equations 3 and 4:

$$\frac{D_{AB}t}{D^2} \tag{3}$$

D_{AB} = the diffusivity of the contaminant through water, (cm^2/sec), is defined in Equation 5

D = the diameter of a water droplet within the shower spray, (cm), assumed to be 0.15 inches or 0.38 cm

t = the time the droplet is suspended in air, (1 sec)

The second dimensionless equation is

$$\frac{P_A{*} - P_{AB}}{P_A{*} - P_{AO}} \tag{4}$$

Where: $P_A{*}$ = initial concentration of contaminant in air, (assumed to be zero)

P_{AO} = See Equation 2

P_{AB} = See Equation 2

The equation for D_{AB} is as follows:

$$D_{AB} = (7.4\times10^{-8}) \quad \frac{(T)\,(x)\,(M_b)^{1/2}}{(N_B)\,(V_a)\,(0.6)} \tag{5}$$

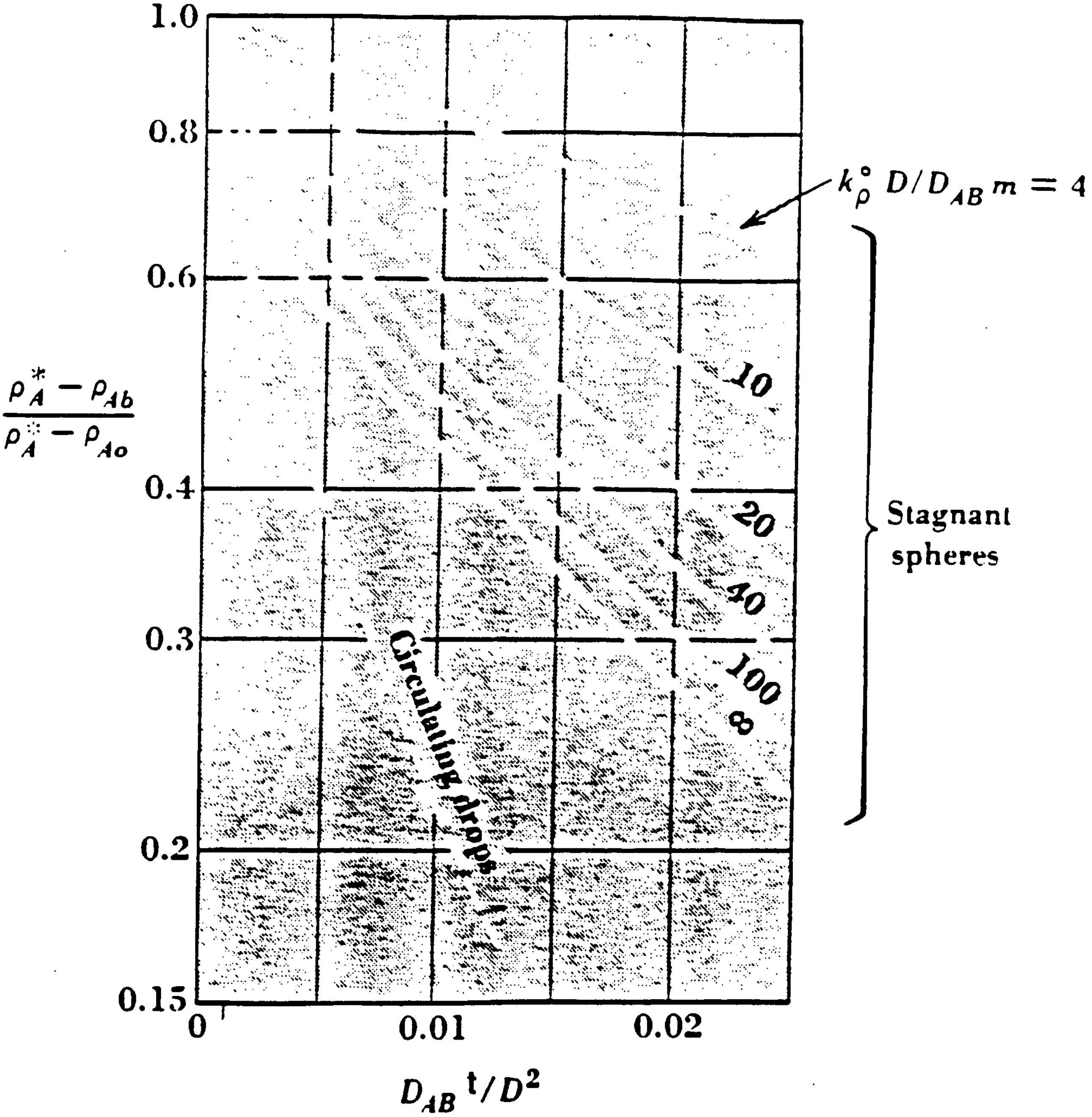
T = atmospheric temperature, (304 K)

N_B = viscosity of water, (1 cp)

x = association parameter, (dimensionless)

M_b = molecular weight of contaminant, (g/g-mole)

V_a = molar volume of contaminant, (cm^3/g-mole)



BENNETT,1974

FIGURE 8-1

CORRELATION FOR DETERMINING CONTAMINANT DIFFUSION THROUGH A DROP OF WATER

NUS CORPORATION

In synopsis the assumptions for these calculations are as follows:

Q = sprayer flow rate = 10 L/min
D = spray droplet diameter = 0.38 cm
t = time the spray is in air = 1 second
P_{AO} = initial contaminant concentration of water spray, same as groundwater concentrations
T = outside temperature = 304 K
P_A^* = initial contaminant concentration in air = 0 mg/m^3
V = volume of bathroom = 12 m^3
ERP = the average contaminant concentration in air which a person is likely to be exposed to while showering

The sequence of steps used in calculating the final average concentration of indicator chemicals in air from shower water is as follows:

- o Determine the diffusitivies, DAB, of each contaminant using Equation 5.
- o Calculate the rate of volatilization, ERX, using Equations 2 and 3 and Figure 8-1.
- o The average concentration of indicator chemicals in air, ERP, is determined by using Equation 1 and is listed in Table 8-11.

8.7.1.3 Concentrations of Indicator Chemicals in Marshland Sediment

Indicator chemical concentrations must be determined for sediments in the marshland in order to evaluate the health effects caused by ingestion and dermal absorption exposure pathways. The highest marshland sediment concentrations were used for the dermal exposure pathway.

8.7.1.4 Concentrations of Indicator Chemicals in Air From the Marshland

The air exposure point concentrations used for the inhalation exposure at the marshland were determined by using the air sampling results performed by Radian Corporation on August 28 and 29, 1986. The samples selected were those taken two feet above the midpoint of the marshland water.

8.7.2 Quantitation of Carcinogenic Risk and Noncarcinogenic Effects

This section describes the quantitation of the carcinogenic risk and the chronic hazards associated with contaminants emanating from the Ciba-Geigy Site. These values are calculated for each human exposure pathway defined in Section 8.6. The concentrations determined for each human exposure pathway were calculated in Section 8.7.1.

The carcinogenic risk is calculated as shown:

$$\text{Risk} = \text{CPF} \times \text{contaminant concentration} \times \text{lifetime average daily intake}$$

Where the CPF is defined in Section 8.4.1.6 and the **lifetime average daily intake** is a quantity that represents the amount of environmental medium (i.e. groundwater, sediment, air) that contacts the internal or external body surface of a human during each exposure event based on the number of events that occur within an assumed 70-year lifetime. This quantity is expressed in units of mass or volume per unit of body mass per day. The constants used for calculating lifetime average daily intakes and the values for the lifetime average daily intakes used in Tables 8-12 to 8-26 are provided in Appendix E.

The chronic hazard index is calculated as shown:

$$\text{Chronic Hazard Index} = \frac{\text{contaminant concentration} \times \text{lifetime average daily intake}}{\text{AIC}}$$

Where the lifetime daily intake is explained above and the AIC is defined in Section 8.4.1.3.

8.7.2.1 Quantitation of Health Effects for Residential Use Completed Exposure Pathways

This section describes the quantitation of the carcinogenic risks and the chronic hazard indices for the completed human exposure pathway for residential uses of groundwater. This pathway to humans is completed, from the contamination of several residential wells identified in the RI, to humans via the exposure routes of ingestion, dermal absorption, and inhalation. The exposure scenario for each route are listed for each evaluation.

- o <u>Quantitation of Health Effects for Residential Use: Ingestion Route</u>

The ingestion of contaminated water through drinking water from several of the residential wells located in the vicinity of the Ciba-Geigy site has been identified as a completed human exposure pathway.

The carcinogenic risk and chronic hazard for the ingestion of residential well water are provided in Tables 8-12 and 8-13.

- o <u>Quantitation of Health Effects for Residential Use: Dermal Absorption Route</u>

The dermal absorption of contaminated residential well water through showering and other domestic activities has been identified as a completed human exposure pathway.

The carcinogenic risks and chronic hazard indices for the dermal absorption of residential water are summarized in Tables 8-14 and 8-15.

- o <u>Quantitation of Health Effects for Residential Use: Inhalation Route</u>

The inhalation of contaminated air volatilizing from residential water during showering and other domestic activities was identified as a completed human exposure pathway.

The carcinogenic risks and chronic hazard indices for the inhalation exposure to contaminated air from residential water are provided in Tables 8-16 and 8-17.

The total carcinogenic risk and total chronic hazard index for the residential use pathway are presented in Table 8-18.

TABLE 8-12

BASELINE CARCINOGENIC RISK FOR THE INGESTION OF WATER FROM A RESIDENTIAL WELL[(a)]

Indicator Chemical	CPF $(mg/kg/day)^{-1}$	Groundwater Concentration mg/L	Risk
Arsenic	1.50×10^{1}	0.012	4.64×10^{-3}
Benzene	5.20×10^{-2}	0.080	1.07×10^{-4}
Chloroform	8.10×10^{-2}	0.251	5.25×10^{-4}
1,2-Dichloroethane	9.10×10^{-2}	0.006	1.41×10^{-5}
Tetrachloroethene	5.10×10^{-2}	0.150	1.97×10^{-4}
Trichloroethene	1.10×10^{-2}	0.099	2.81×10^{-5}
Total Risk			5.51×10^{-3}

The assumptions were made that a child (age 5 to 18) would drink 1.0 liter of residential well water every day for 13 years, and an adult (age 18 to 70) would drink 2 liters of residential well water every day for 52 years. In addition, the exposure results in 100 percent absorption of ingested contaminants.

(a) See Appendix E (p. E-2) for calculations.

TABLE 8-13

BASELINE CHRONIC HAZARD EVALUATION FOR THE INGESTION OF WATER FROM A RESIDENTIAL WELL[a]

Indicator Chemical	AIC mg/kg/day	Groundwater Concentration mg/L	Chronic Hazard Index
Barium	5.10×10^{-2}	0.395	1.99×10^{-1}
Cadmium	2.90×10^{-4}	0.345	3.07×10^{1}
Chlorobenzene	2.70×10^{-2}	2.170	2.07×10^{0}
Nickel	1.00×10^{-2}	0.612	1.58×10^{0}
1,2,4-Trichlorobenzene	2.00×10^{-2}	0.330	4.25×10^{-1}
Total Chronic Hazard			**3.50×10^{1}**

The assumptions were made that a child (age 5 to 18) would drink 1.0 liter of residential well water every day for 13 years, and an adult (age 18 to 70) would drink 2 liters of residential well water every day for 52 years. In addition, the exposure results in 100 percent absorption of ingested contaminants.

(a) See Appendix E (p. E-2) for calculations.

TABLE 8-14

BASELINE CARCINOGENIC RISK FOR THE DERMAL ABSORPTION OF WATER FROM A RESIDENTIAL WELL[(a)]

Indicator Chemical	CPF $(mg/kg/day)^{-1}$	Groundwater Concentration mg/L	Risk
Arsenic	$1.50x10^{1}$	0.012	(b)
Benzene	$5.20x10^{-2}$	0.080	$1.96x10^{-8}$
Chloroform	$8.10x10^{-2}$	0.251	$9.56x10^{-8}$
1,2-Dichloroethane	$9.10x10^{-2}$	0.006	$2.57x10^{-9}$
Tetrachloroethene	$5.10x10^{-2}$	0.150	$3.60x10^{-8}$
Trichloroethene	$1.10x10^{-2}$	0.099	$5.12x10^{-9}$
Total Risk			$1.59x10^{-7}$

The assumptions were made that an individual over a lifetime would be exposed to the water from a residential well (through showering and other uses) for 25 min/day, 7 days/week for 52 weeks/year. The body is 80 percent immersed and it is further assumed that the flux rate of water through human skin is $5x10^{-7}$ L/cm^2-hr, and the absorption of contaminants through human skin is 12 percent.

(a) See Appendix E (p. E-3) for calculations.

(b) Inorganic arsenic is not dermally absorbed.

TABLE 8-15
BASELINE CHRONIC HAZARD EVALUATION FOR THE DERMAL ABSORPTION OF WATER FROM A RESIDENTIAL WELL(a)

Indicator Chemical	AIC mg/kg/day	Groundwater Concentration mg/L	Chronic Hazard Index
Barium	5.10×10^{-2}	0.395	(b)
Cadmium	2.90×10^{-4}	0.345	(b)
Chlorobenzene	2.70×10^{-2}	2.170	3.78×10^{-4}
Nickel	1.00×10^{-2}	0.612	(b)
1,2,4-Trichlorobenzene	2.00×10^{-2}	0.330	7.76×10^{-5}
Total Chronic Hazard			4.56×10^{-4}

The assumptions were made that an individual over a lifetime would be exposed to the water from a residential well (through showering and other uses) 25 min/day, 7 days/week for 52 weeks/year. The body is 80 percent immersed and it is further assumed that the flux rate of water through human skin is 0.5 mg/cm^2-hr, and the absorption of contaminants through human skin is 12 percent.

(a) See Appendix E (p. E-3) for calculations.

(b) Inorganic barium, cadmium, and nickel are not dermally absorbed.

TABLE 8-16

BASELINE CARCINOGENIC RISK FOR THE INHALATION EXPOSURE FROM RESIDENTIAL WATER(a)

Indicator Chemical	CPF $(mg/kg/day)^{-1}$	Air Concentration mg/m^3	Risk
Arsenic(b)	----------	----------	----------
Benzene	2.60×10^{-2}	6.94×10^{-6}	1.39×10^{-9}
Chloroform	8.10×10^{-2}(c)	1.39×10^{-5}	8.70×10^{-9}
1,2-Dichloroethane	3.50×10^{-2}	6.94×10^{-7}	1.88×10^{-10}
Tetrachloroethene	1.70×10^{-3}	6.94×10^{-6}	9.12×10^{-11}
Trichloroethene	4.60×10^{-3}	6.94×10^{-6}	2.47×10^{-10}
Total Risk			1.06×10^{-8}

The assumptions were made that a child (age 5 to 18) and adult (age 18 to 70) would be exposed to the air in a bathroom everyday for 25 minutes in a shower and 10 minutes in the bathroom after showering. It was further assumed that the respiration rates of the child and adult are 15 m^3/day and 23 m^3/day, respectively.

(a) See Appendix E (p. E-4) for calculations.

(b) Arsenic does not volatilize from water.

(c) The CPF for the oral route was used.

TABLE 8-17
BASELINE CHRONIC HAZARD EVALUATION FOR THE INHALATION EXPOSURE FROM RESIDENTIAL WATER(a)

Indicator Chemical	AIC mg/kg/day	Air Concentration mg/m^3	Chronic Hazard Index
Barium(b)	----------	----------	----------
Cadmium(b)	----------	----------	----------
Chlorobenzene	5.70×10^{-3}	1.53×10^{-4}	2.07×10^{-4}
Nickel(b)	----------	----------	----------
1,2,4-Trichlorobenzene	2.00×10^{-2}(c)	2.08×10^{-5}	8.04×10^{-6}
Total Chronic Hazard			**2.15×10^{-4}**

The assumptions were made that a child (age 5 to 18) and adult (age 18 to 70) would be exposed to the air in a bathroom everyday for 25 minutes in a shower and 10 minutes in the bathroom after showering. It was further assumed that respiration rates of the child and adult are 15 m^3/day and 23 m^3/day, respectively.

(a) See Appendix E (p. E-4) for calculations.

(b) Barium, cadmium, and Nickel do not volatilize from water.

(c) The AIC for oral route was used; no AIC for inhalation route was available.

TABLE 8-18

TOTAL BASELINE CARCINOGENIC RISKS AND CHRONIC HAZARD EVALUATION FOR COMPLETED RESIDENTIAL USE PATHWAYS

Exposure Route	Carcinogenic Risk$\times 10^{-6}$	Total Chronic Hazard
Ingestion of Water from a Residential Well	5510.0	3.50×10^{1}
Dermal Absorption of Water from a Residential Well	0.159	4.56×10^{-4}
Inhalation Exposure from Residential Water	0.0106	2.15×10^{-4}

TOTAL RISK (PER MILLION POPULATION) 5510×10^{-6}

TOTAL CHRONIC HAZARD $\frac{(CDI)}{(ACI)}$ 3.50×10^{1}

8.7.2.2 Quantitation of Health Effects for Recreation Use Completed Pathways

This section describes the quantitation of the carcinogenic risks and chronic hazard indices for the completed human exposure pathway for recreational uses of the marshland. This pathway is completed to humans for the exposure routes of ingestion, dermal absorption and inhalation. The exposure scenario for each completed pathway and exposure route are listed for each evaluation.

- Quantitation of Health Effects from Recreational Use: Ingestion Route

The ingestion of contaminated sediment during recreational use of the marshland area has been identified as a human exposure route. The community can come in contact with contaminants through the accidental ingestion of sediments from the marshland area. The carcinogenic risks and chronic hazards for the ingestion of marshland sediment are provided in Table 8-19 and Table 8-20.

- Quantitation of Health Effects from Residential Use: Dermal Absorption Route

The dermal exposure to marshland sediments contaminated with indicator chemicals has been identified as a completed human exposure route. The contaminants in sediments directly contact the skin through dermal exposure to the sediments in the marshland area. The carcinogenic risks and chronic hazards for the dermal exposure to the marshland sediments during recreation are provided in Tables 8-21 and 8-22. Only organic indicator chemicals have been evaluated because no dermal absorption of ionic inorganic indicator chemicals can occur through intact skin.

TABLE 8-19
BASELINE CARCINOGENIC RISK FOR THE INGESTION OF MARSHLAND SEDIMENT[(a)]

Indicator Chemical	CPF $(mg/kg/day)^{-1}$	Sediment Concentration mg/kg	Risk
Arsenic	1.50×10^{1}	NA[(b)]	---------
Benzene	5.20×10^{-2}	2.25	1.50×10^{-8}
Chloroform	8.10×10^{-2}	3.63	3.76×10^{-8}
1,2-Dichloroethane	9.10×10^{-2}	0.03	3.49×10^{-10}
Tetrachloroethene	5.10×10^{-2}	4.78	3.12×10^{-8}
Trichloroethene	1.10×10^{-2}	0.53	7.46×10^{-10}
Total Risk			**8.49×10^{-8}**

The assumptions were made that an individual over a lifetime would be exposed to the marshland sediment 2 days/week for 15 weeks/year. It was further assumed that during each exposure both the adult and child would each ingest 100 mg of sediment and the exposure would result in 100 percent absorption of contaminants.

(a) See Appendix E (p. E-5) for calculations.

(b) Not Analyzed.

TABLE 8-20

BASELINE CHRONIC HAZARD EVALUATION FOR THE INGESTION OF MARSHLAND SEDIMENT(a)

Indicator Chemical	AIC mg/kg/day	Sediment Concentration mg/kg	Chronic Hazard Index
Barium	$5.10\text{x}10^{-2}$	NA(b)	---------
Cadmium	$2.90\text{x}10^{-4}$	NA	---------
Chlorobenzene	$2.70\text{x}10^{-2}$	4.84	$2.30\text{x}10^{-5}$
Nickel	$1.00\text{x}10^{-2}$	NA	---------
1,2,4-Trichlorobenzene	$2.00\text{x}10^{-2}$	4.95	$3.17\text{x}10^{-5}$
Total Chronic Hazard			$5.47\text{x}10^{-5}$

The assumptions were made that an individual over a lifetime would be exposed to the marshland sediment 2 days/week for 15 weeks/year. It was further assumed that during each exposure both the adult and child would each ingest 100 mg of sediment and the exposure would result in 100 percent absorption of contaminants.

(a) See Appendix E (p. E-5) for calculations.

(b) Not Analyzed.

TABLE 8-21
BASELINE CARCINOGENIC RISK FOR DERMAL ABSORPTION OF MARSHLAND SEDIMENT[(a)]

Indicator Chemical	CPF $(mg/kg/day)^{-1}$	Sediment Concentration mg/kg	Risk
Arsenic	1.50×10^{1}	NA(b)	---------
Benzene	5.20×10^{-2}	2.25	5.60×10^{-8}
Chloroform	8.10×10^{-2}	3.63	1.41×10^{-7}
1,2-Dichloroethane	9.10×10^{-2}	0.03	1.31×10^{-9}
Tetrachloroethene	5.10×10^{-2}	4.78	1.17×10^{-7}
Trichloroethene	1.10×10^{-2}	0.53	2.79×10^{-9}
Total Risk			**3.18×10^{-7}**

The assumptions were made that an individual over a lifetime would be exposed to the marshland sediment 2 days/week for 15 weeks/yr. It was further assumed that both the child and adult would expose half of their body surface areas resulting in deposition of 2.77×10^{-6} kg/cm^2-day of sediment. In addition, the dermal absorption of contaminant from sediment to human skin is 15 percent of the absorption when the contaminant is applied directly (12 percent), which results in a 1.8 percent absorption from sediment through human skin.

(a) See Appendix E (p. E-6) for calculations.

(b) Not Analyzed.

TABLE 8-22

BASELINE CHRONIC HAZARD EVALUATION FOR THE DERMAL ABSORPTION OF MARSHLAND SEDIMENT(a)

Indicator Chemical	AIC mg/kg/day	Sediment Concentration mg/kg	Chronic Hazard Index
Barium	5.10×10^{-2}	NA(b)	---------
Cadmium	2.90×10^{-4}	NA(b)	---------
Chlorobenzene	2.70×10^{-2}	4.84	8.59×10^{-5}
Nickel	1.00×10^{-2}	NA(b)	---------
1,2,4-Trichlorobenzene	2.00×10^{-2}	4.95	1.19×10^{-4}
Total Hazard			2.05×10^{-4}

The assumptions were made that an individual over a lifetime would be exposed to the marshland sediment 2 days/week for 15 weeks/yr. It was further assumed that both the child and adult would expose half of their body surface areas resulting in deposition of 2.77×10^{-6} kg/cm^2-day of sediment. In addition, the dermal absorption of contaminant from sediment to human skin is 15 percent of the absorption when the contaminant is applied directly (12 percent), which results in a 1.8 percent absorption from sediment.

(a) See Appendix E (p. E-6) for calculations.

(b) Not Analyzed.

(c) Inorganic barium, cadmium, and nickel are not dermally absorbed.

o Quantitation of Health Effects from Recreational Use: Inhalation Route

The inhalation exposure to contaminated air volatilizing from the marshland area during recreational use has been identified as a human exposure route. The contaminants in air can be inhaled directly from organic chemicals which have volatilized from the marshland area surface water. The carcinogenic risks and chronic hazard for inhalation of contaminated air during recreation are provided in Table 8-23 and Table 8-24.

The total carcinogenic risk and the total chronic hazard evaluation for the recreational use pathway are presented in Table 8-25.

8.8 Summary and Conclusions of the Quantitative Baseline Public Health Evaluation

The quantitative baseline public health evaluation of the Ciba-Geigy Site presented a chemical and toxicological assessment of the contaminants emanating from the site as described in the remedial investigation report and other studies of this Superfund site. The methodology used in this evaluation is consistent with Superfund Public Health Evaluation Manual (EPA, 1986). However, the evaluation is limited to those chemicals covered in the remedial investigation; routine plant emissions in compliance with New Jersey State and Federal guidelines are not included.

As part of the baseline evaluation, specific completed human pathways were developed for the standard ingestion, inhalation, and dermal exposure routes and, these completed pathways currently exist.

The baseline quantitative carcinogenic risk assessment for the Ciba-Geigy Site presents the human risk per million population. The baseline chronic hazard assessment presents an indicator ratio of the chronic effects of indicator chemicals, and if greater than 1, chronic health effects are possible.

TABLE 8-23
BASELINE CARCINOGENIC RISK FOR THE INHALATION EXPOSURE FROM CONTAMINATED AIR FROM THE MARSHLAND[a]

Indicator Chemical	CPF $(mg/kg/day)^{-1}$	Air Concentration mg/m^3	Risk
Arsenic[b]	----------	----------	---------
Benzene	2.60×10^{-2}	2.07×10^{-3}	2.34×10^{-7}
Chloroform	8.10×10^{-2}[c]	1.08×10^{-2}	3.81×10^{-6}
1,2-Dichloroethane	3.50×10^{-2}	NA	---------
Tetrachloroethene	1.70×10^{-3}	8.10×10^{-3}	5.99×10^{-8}
Trichloroethene	4.60×10^{-3}	3.98×10^{-2}	7.96×10^{-7}
Total Risk			**4.90×10^{-6}**

The assumptions were made that an individual would be exposed to the air at the marshland for 4 hours/day, 2 days/wk for 15 weeks/yr. It was further assumed that a child (age 5 to 18) and an adult (age 18 to 70) have respiration rates of 15 m^3/day and 23 m^3/day, respectively. In addition, the exposure results in 100 percent absorption of inhaled contaminants.

(a) See Appendix E (p. E-7) for calculations.

(b) Arsenic does not volatilize from soil or water.

(c) The CPF for the oral route was used.

TABLE 8-24

BASELINE CHRONIC HAZARD EVALUATION FOR THE INHALATION EXPOSURE FROM CONTAMINATED AIR FROM THE MARSHLAND(a)

Indicator Chemical	AIC mg/kg/day	Air Concentration mg/m^3	Chronic Hazard Index
Barium(b)	----------	----------	----------
Cadmium(b)	----------	----------	----------
Chlorobenzene	5.70×10^{-3}	1.01×10^{-2}	7.71×10^{-3}
Nickel(b)	----------	----------	----------
1,2,4-Trichlorobenzene	2.00×10^{-2}	NA(c)	----------
Total Hazard Index			**7.71×10^{-3}**

The assumptions were made that an individual would be exposed to the air at the marshland for 4 hours/day, 2 days/wk for 15 weeks/yr. It was further assumed that a child (age 5 to 18) and an adult (age 18 to 70) have respiration rates of 15 m^3/day and 23 m^3/day, respectively. In addition, the exposure results in 100 percent absorption of inhaled contaminants.

(a) See Appendix E (p. E-7) for calculations.

(b) Barium, cadmium, and nickel do not volatilize from soil or water.

(c) Not Analyzed.

TABLE 8-25
TOTAL BASELINE CARCINOGENIC RISKS AND CHRONIC HAZARD EVALUATION FOR COMPLETED RECREATIONAL USE PATHWAYS

Exposure Route	Carcinogenic Riskx10^{-6}	Total Chronic Hazard
Ingestion of Marshland Sediment	0.0849	5.47×10^{-5}
Dermal Absorption of Marshland Sediment	0.318	2.05×10^{-4}
Inhalation Exposure from Contaminated Air from the Marshland	4.90	7.71×10^{-3}
TOTAL RISK (PER MILLION POPULATION)	5.30	
TOTAL CHRONIC HAZARD $\frac{(CDI)}{(ACI)}$		7.97×10^{-3}

8.8.1 Baseline Public Health Evaluation and the Indicator Chemical Selection

The quantitative baseline public health evaluation uses the indicator chemical selection process described in Section 8.2. Six chemicals were selected for carcinogenic evaluation and five chemicals were selected for noncarcinogenic evaluation. The indicator chemical's toxicity and fate assessments provided the process and ranking order procedure. While most site contaminants were ranked some contaminants were not ranked because of a lack of information currently available. None of the unranked contaminants were human carcinogens or were present in a specific media in quantities that could present a baseline health risk or chronic hazard.

8.8.2 Baseline Public Health Evaluation and the Completed Pathways of Exposure

Residents in the vicinity east of the Ciba-Geigy Site have wells and use the water for a variety of residential and recreational uses as described in Section 8.6. Although the use of these off-site wells has diminished since completion of the RI there remain wells that constitute completed human exposure pathways under the baseline evaluation.

The completed pathways include the ingestion, dermal absorption, and inhalation of contaminants present in groundwater from residential use and of contaminants present in sediment and groundwater for recreational use. These baseline contaminant concentrations are the maximum concentrations present at the human exposure points and reflect the conditions off site as it exists today.

8.8.3 Quantitative Baseline Public Health Evaluation

The quantitative baseline public health evaluation summarizes the total carcinogenic risk and noncarcinogenic chronic hazard index for the completed human exposure pathways identified at the Ciba-Geigy Site. This baseline public health evaluation is based on the contaminant concentrations currently emanating from the Ciba-Geigy Site.

In order to present a unifying number to the baseline public health evaluation, the sum of the carcinogenic risks and noncarcinogenic chronic hazard indices for the completed exposure pathways are presented in Table 8-26. These sums include the total carcinogenic risk and noncarcinogenic chronic hazard index for both the residential and recreational exposure pathways, as well as, the total carcinogenic risk and noncarcinogenic chronic hazard index posed by only the recreational exposure pathway.

Under baseline completed human exposure conditions to site contaminants, the carcinogenic risk of $5{,}513 \times 10^{-6}$ indicates that the risk of contracting cancer increases by 5,513 in a million population. While this risk is excessive, it is almost entirely from the residential exposure scenarios. If all residential wells are capped, the human exposure is only from recreational use and the carcinogenic risk decreases to 5 in a million population which is still unacceptable.

The baseline chronic hazard evaluation presents a comparison (ratio) of the chronic health effects (CDI) to the acceptable chronic intakes (ADI) as defined in Section 8.4. If the value is greater than 1, then chronic human health effects are possible. Table 8-26 presents the total baseline chronic hazard index for the completed exposure pathways which includes residential and recreational exposure, and indicates with an index greater than 1, that there is a chance of demonstrating a chronic health effect from the noncarcinogenic indicator chemicals. The total chronic hazard index for the completed exposure pathways without residential uses indicates, with an index less than 1, that there is not a chronic human health effect from the noncarcinogenic indicator chemicals. As with the carcinogenic risk numbers, the chronic health hazard index is almost entirely based on the residential exposure scenarios. If all wells are capped, there is not a chronic health hazard due to exposure through recreational exposure pathways.

The baseline health evaluation for exposure to humans from contaminants emanating from the Ciba-Geigy Site demonstrates that the population will be exposed to an unacceptable carcinogenic risk, and feasible alternatives to lower these contaminant concentrations need to be addressed.

TABLE 8-26

TOTAL BASELINE CARCINOGENIC RISK AND CHRONIC HAZARD INDEX FOR ALL COMPLETED EXPOSURE PATHWAYS

Exposure Route	Carcinogenic Risk ($x10^{-6}$)		Chronic Hazard	
Residential	5510.0		35.0	
Recreational	5.3	5.3	0.00797	0.00797
Total Carcinogenic Risk (per million population)	5513.3	5.3		
Total Chronic Hazard Index $\frac{(CDI)}{(AIC)}$			35.0	0.00797

R

REFERENCES

Amdurer, M., R.T. Fellman, J. Roetzer, and C. Russ, 1986. Systems to accelerate in-situ stabilization of waste deposits, Envirosphere Company, New York, EPA Report No. 540/2-86/002.

Anderson, H.R., and C.A. Appel, 1969. Geology and groundwater resources of Ocean County, New Jersey. N.J. Dept. of Conservation and Economic Development, Special Report 29, 73 p.

AWARE Inc., November 1984. Interim status report, Recovery well system for Ciba-Geigy Corp., Toms River Plant, New Jersey and Ardsley, New York.

AWARE Inc., 1984. Evaluation of aquitard effectiveness, Cardinal Drive Area. Prepared by J.H. Clarke, M.R. Groves, and M.R. Corn. Associated Water and Air Resources Engineers, Incorporated.

AWARE Inc., 1986. Hydrogeologic and related environmental investigation, prepared for Ciba-Geigy Corporation, Toms River Plant, Toms River, New Jersey.

AWARE Inc., 1987. Supplemental investigations of the former river lagoon and former sludge disposal area, prepared for Ciba-Geigy Corporation, Toms River Plant, Toms River, New Jersey.

Baker, V.E., May 15, 1985. Information regarding potential hazardous waste and hazardous waste constituent releases from solid waste management units. Ciba-Geigy Corporation. Submitted to U.S. EPA Solid Waste Branch.

Barth, D.S. and B.J. Mason, 1984. Soil sampling quality assurance user's guide. EPA-600/4-84-043.

Bobsein, W.P., December 13, 1977. Correspondence to B.S. Tylutki of New Jersey Department of Environmental Protection, "Re: Facility Registration No. 1507C".

Bohn, H.L. McNeal and G.A. O'Connor, 1979. Soil chemistry. New York, John Wiley and Sons.

Bowen, H.J.M., 1979. Environmental chemistry of the elements. New York, Academic Press.

Bruckner, J.V. and R.G. Peterson, 1976. Evaluation of toluene toxicity utilizing the mouse as an animal model of human solvent abuse. The Pharmacol, 18:244.

Carter, C.H., 1978. A regressive barrier and barrier-protected deposit: depositional environments and geographic setting of the Late Tertiary Cohansey sand. Journal of Sedimentary Petrology, 48, (3): 933-950.

Catalytic Inc., 1977. Engineering design report, existing chemical landfill closure for the Toms River Chemical Corporation, Landfill Facility No. 1507B.

Cesareo, D.J., and A. Morales, March 20, May 1, June 3, 1980. Hazardous waste site investigations. U.S. EPA Region 2, New York, New York.

Ciba-Geigy Corporation, June, 1986. Memo from B.J. Berdahl, Compliance Manager, Ciba-Geigy, to N. Capuano, NUS.

Clement Associates, Inc. (CAI), December, 1983. Remedial Action Master Plan (RAMP), Toms River Chemical Company, Toms River, New Jersey.

Clement Associates, Inc., 1985. Chemical, physical, and biological properties of compounds present at hazardous waste sites. Prepared for U.S. EPA. Clement Associates, Inc. Arlington, VA.

Cogbill, C.V., and G.E. Likens, 1974. Acid precipitation in the northeastern United States. Water Resources Research, 10:1133-1137.

EAC, May 24, 1978. Environmental impact statement for the proposed lined landfill. Environmental Assessment Council, Inc., prepared by Thomas J. Concannon.

Environmental Photographic Interpretation Center (EPIC), September 6, 1984. Toms River Chemical Preliminary Site Analysis Results.

EPA, 1979. Water-related environmental fate of 129 priority pollutants. EPA 440/4-79-029 Washington, D.C.

EPA, 1980. Ambient water quality criteria for chlorinated benzenes. Office of Water Regulations and Standards Criteria Division, Washington, D.C. PB81-117392.

EPA, January 4, 1980. Hazardous waste site investigation, Toms River Chemical, Toms River, New Jersey. U.S. EPA, Prepared by J. Jimenez.

EPA, 1980a. Water quality criteria documents; availability. Federal Register. 45(231): 79318-79379.

EPA, 1984. Health Effects Assessment for:
    Arsenic. Final Draft. ECAO-CIN-H016.
    Barium. Final Draft. ECAO-CIN-H021.
    Benzene. Final Draft. ECAO-CIN-H037.
    Benzo(a)pyrene. Final Draft. ECAO-CIN-H022.
    Chlorobenzene. Final Draft. ECAO-CIN-H040.
    Chloroform. Final Draft. ECAO-CIN-H010.
    Lead. Final Draft. ECAO-CIN-H055.
    Nickel. Final Draft. ECAO-CIN-H018.
    Selenium. Revised Final Draft. ECAO-CIN-H058.
    Tetrachloroethylene. Final Draft. ECAO-CIN-H009.
    Trichloroethylene. Final Draft. ECAO-CIN-H046.
    Zinc. Revised Final Draft. ECAO-CIN-H048.
Prepared for Office of Emergency and Remedial Response by Environmental Criteria and Assessment Office, Cincinnati, OH.

EPA, 1985a. 40 CFR Parts 141 and 142. National Primary Drinking Water Regulations; Volatile Synthetic Organic Chemicals; Final Rule and Proposed Rule. Federal Register. 50(219): 46880-47022.

EPA, 1985a. Health advisories for 52 chemicals which have been detected in drinking water. Report Number PB86-118336. U.S. EPA Office of Drinking Water. National Technical Information Service, U.S. Department of Commerce, Springfield, VA.

EPA, 1986. Superfund public health evaluation. Office of Emergency and Remedial Response, Office of Solid Waste and Emergency Response. U.S. EPA, Washington, D.C. 20460.

EPA, 1986a. Superfund exposure assessment and manual draft. Prepared for Office of Emergency and Remedial Response, Office of Solid Waste and Emergency Response, U.S. EPA, Washington, D.C., 20460.

Federal Water Quality Criteria Documents, November 28, 1980. Phthalate Esters. Federal Register.

Fetter, C.W. Jr., 1980. Applied hydrogeology. Columbus, Ohio, Charles E. Merrill Publishing Company.

Forman, R.T.T., 1979. Pine Barrens ecosystem and landscape. New York, Academic Press.

Freund, J.E. and R.E. Walpole, 1980. Mathematical statistics. Englewood Cliffs, New Jersey, Prentice-Hall Inc.

Geonics Inc., September 25, 1978. "Groundwater Elevations at Landfill Site", correspondence to J. McPherson of Ciba-Geigy, Toms River Chemical Corp.

Geonics Inc., December, 1980. Phase 1, Geohydrological Investigation, Toms River, New Jersey, for Toms River Chemical Corp.

Geonics, 1981. Letter to W. Saunders, Bureau of Groundwater Management, NJDEP, from Fred Fox, Geonics, May 4, 1981.

Geonics, 1982. Final report: Phase 2 geohydrological investigation, Toms River plant.

Gill, H.E., and G.M. Farlekas, 1976. Geohydrologic maps of the Potomac-Raritan-Magothy Aquifer System in the New Jersey coastal plain. U.S. Geological Survey Hydrologic Investigations Atlas HA-557.

ICF Incorporated, 1985. Draft Superfund public health evaluation manual. Prepared for U.S. EPA, Office of Solid Waste and Emergency Response. ICF Incorporated, Washington, D.C.

IRIS, March 3, 1987. Integrated Risk Information System chemical files. Office of Health and Environmental Assessment, U.S. EPA, Washington, D.C.

Isphording, W.C., and W. Lodding, November, 1969. Facies changes in sediments of the Miocene age, in Subitsky, Seymour, Ed., Geology of selected areas in New Jersey and eastern Pennsylvania and gradebook of excursions: Geological Society of America and associated societies. Annual Meeting, Atlantic City, New Jersey, New Brunswick, New Jersey, Rutgers University Press. p. 7-13.

Isphording, W.C., 1970, Petrology, stratigraphy and re-definition of the Kirkwood Formation (Miocene) of New Jersey. Journal of Sedimentary Petrology, 40, (4): 986-997.

Kelsey H.M., and D.J.J. Kinsman, 1971. Hydrological and geochemical studies of New Jersey Pine Barrens rivers. Geol. Soc. Amer. Abstr. 3.

Kenaga, E.E., 1980. Predicted bioconcentration factors and soil sorption coefficients of pesticides and other chemicals. Ecotoxicology and Environmental Safety, 4:26-38.

Kimbrough, R.D., H. Falk, and P. Stehr, 1984. Health implications of 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) contamination of residential soil. Journal of Toxicology and Environmental Health. 14:47-93.

Kitchin, K.T., and M.T. Ebron, 1983. Material hepatic and embryonic effects of 1,2,4-trichlorobenzene in the rat. Environmental Research 31:362-373.

Mackay, D.M., P.V. Roberts, and J.A. Cherry, 1985. Transport of organic contaminants in groundwater. Environmental Science and Technology. 19(5):384-392.

Markewicz, Frank J., August 26, 1986. Letter report on field investigation at Toms River Chemical Co., New Jersey Department of Environmental Protection.

McNeill, J.D., 1980. Technical Note TN-8 EM34-3 Survey Interpretation Techniques, Geonics Limited, Ontario, Canada.

Means, J.L., R.F. Yuretich, D.A. Crerar, D.J.J. Kinsman, and M.P. Borcsik, 1981. Hydrogeochemistry of the New Jersey Pine Barrens. Department of Geological and Geophysical Sciences. Princeton University, Princeton, New Jersey.

Menzer, R.E. and J.D. Nelson, 1980. Water and soil pollutants. Chapter 25 in Dou'll, J. Khasen, C.D. and Andur, M.D. Toxicology, MacMillan.

National Flood Insurance Program, June 15, 1983. FIRM Flood Insurance Rate Map, Township of Dover, New Jersey, Ocean County, Federal Emergency Management Agency.

National Oceanic and Atmospheric Administration (NOAA), September, 1982. Climatograph of the United States No. 81, Monthly normals of temperature, precipitation, and heating and cooling degree days, 1951-1980, New Jersey. Asheville, North Carolina.

New Jersey Dept. of Environmental Protection, 1983, memo dated 09/01/83 to T. Stone from K.G. Andres, Review of Geonics Phase 3 Report, Toms River Facility, Ciba-Geigy Corporation.

Newsom, J.M., 1985. Transport of organic compounds dissolved in groundwater. Groundwater Monitoring Review, 5(3):28-36.

Ocean County Planning Board, 1978, Groundwater Management. 208 Water Management, Ocean County, Toms River, New Jersey, 409p.

Ocean County Planning Board, January, 1978. Population, land use, and environmental resources; Ocean County and Southern Monmouth County, New Jersey.

Olsson, R.K., 1975. Upper Cretaceous and Lower Tertiary Stratigraphy of New Jersey Coastal Plain: Petroleum Exploration Society of New York, New York, Second Annual Field Trip Guidebook. 49p.

Parr, J.E., P.B. Marsh, and J.M. Kla, 1983. Land treatment of hazardous wastes. Noyes Data Corp., Park Ridge, New Jersey.

Pennak, R.W., 1978. Fresh-water invertebrates of the United States. New York, Ronald Press Co.

Perry, W.J. Jr., J.P. Minead, E.G.A. Weed, E.I. Robins, and E.C. Rhodehamel, 1975. Stratigraphy of Atlantic coastal margin of United States north of Cape Hatteras - brief survey: American Association of Petroleum Geologists Bulletin, v. 59, p. 1529-1548.

Pielou, E.C., 1975. Ecological diversity, New York, John Wiley and Sons, Inc.

Pucknat, A.W., ed., 1981. Health impacts of polynuclear aromatic hydrocarbons. Noyes Data Corp., Park Ridge, New Jersey.

Rhodehamel, E.C., 1970. A hydrologic analysis of the Pine Barrens region. N.J. Water Policy Board Circular No. 22.

Rhodehamel, E.C., 1973. Geology and water resources of the Wharton Tract and the Mullica River Basin in southern New Jersey. N.J. Div. Water Resources Special Report 36.

Richards G.G., 1945. Subsurface Stratigrapy of Atlantic Coastal Plain between New Jersey and Georgia: American Association of Petroleum Geologists. Bulletin, 29, No. 7, p. 885-955.

Richards, G.I.G., 1961. New evidence for marine phase of Raritan Formation (Cretaceous) in New Jersey Coastal Plain: American Association of Petroleum Geologists. Bulletin, 45, p. 1755-1758.

Roberts, P.V., J. Schreiner and G.D. Hopkins, 1982. Field study of organic water quality changes during groundwater Recharge in the Palo Alto Baylands. Water Research, 16:1025.

Seaber, P.R. 1965. Variations in chemical character of water in the Englishtown Formation, New Jersey; U.S. Geological Survey Professional Paper 498-B, 35p.

Shannon, C.E., and W. Weaver, 1963. The mathematical theory of communication. Urbana, University of Illinois Press.

Simpson, E.H., 1949. Measurement of diversity. Nature. p.163-688.

Toms River Chemical Corporation (TRC), February 14, 1975. Analysis of landfilled chemical waste of Toms River Chemical Corporation.

Trautman, C.J., May 30, 1984. Toms River Chemical - Ciba-Geigy Chronology of Inspections from May 22, 1979 to May 14, 1984.

Ure, A.M., et al. 1983. Elemental constituents of soil in environmental chemistry, Vol. 2. London, U.K, Burlinghouse.

U.S.G.S. Water Data: NJ-64-1 to NJ-84-1. United States Geological Survey.

Weast, R.C., ed., 1981-1982. CRC handbook of chemistry and physics. 62nd ed. Florida, CRC Press.

Weston Geophysical, 1986. Geophysical Survey, Toms River Chemical Company Site, Toms River, New Jersey.

Wetzel, R.G., 1975. Limnology. Philadelphia, W.B. Saunders Co.

Wilson, J.T. and C.G. Enfield, 1983. Biological transformation of organic pollutants in groundwater. EOS. 64(33):505.

World Health Organization, 1979. DDT and its derivatives. Environmental Health Criteria 9. World Health Organization, Geneva.

World Health Organization, 1984. Chlordane. Environmental Health Criteria 34. World Health Organization, Geneva.

Wood, P.R., F.Z. Parsons, R.F. Lang, and I.L. Payan, 1981. Introductory Study of the Biodegradation of the Chlorinated Methane, Ethane, and Ethene Compounds. Presented at the American Water Works Association Annual Conference and Exposition, June 7-11, St. Louis, MO.

Zapecza, Otto S., 1984. Hydrogeologic framework of the New Jersey Coastal Plain, Regional aquifer systems analysis, U.S. Geological Survey, Open File Report 84-730.