Case-control Study of Childhood Cancers in Dover Township (Ocean County), New Jersey

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Appendix A: Occurrence and Diversity of Childhood Cancers

In New Jersey, an average of 14.3 new cases of cancer per 100,000 children under the age of 15 years occurred each year in the period 1979 through 1995. In comparison, the estimated annual rate in the United States was 13.6 cases per 100,000 children in a similar time period (NCI, 1996). Leukemias are the most common type of cancer that occur in children under age 15, accounting for 31% of cancers in New Jersey in this age group. Brain and central nervous system cancers account for 20% of new childhood cancer cases, and sympathetic nervous system cancers account for 7.5% of new cancer cases in children under age 15 (NJDHSS, 1999).

Nationally, the overall incidence of childhood cancers has increased since the mid-1970's, but rates in the past decade have been fairly stable (Ries et al., 1999; NCI, 1996; Zahm and Devesa, 1995). Childhood leukemia incidence has continued to increase over this same time period, with the trend primarily reflecting an increase in acute lymphocytic leukemia. Childhood brain and central nervous system cancers appear to have increased over the past two decades (Ries et al., 1999). The increases may be due to diagnostic improvements that have occurred over the past 20 years, better case ascertainment, or may reflect real increases in incidence due to unknown factors. Over the past two decades, there has been little indication of an increase in the overall incidence of sympathetic nervous system cancers (Ries et al., 1999).

Survival rates for many types of childhood cancer have been improving in recent years due to advances in diagnosis and treatment. In New Jersey, cancer mortality rates have been dropping steadily, from 4.2 deaths per 100,000 children under age 15 in 1980 to 3.0 per 100,000 in 1994 (NJDHSS, 1999). Cancer, however, remains the second leading cause of death among children under age 15 years.

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Appendix B: Literature Review of Potential Risk Factors

The National Cancer Institute publication *Cancer Incidence and Survival among Children and Adolescents: United States SEER Program 1975-1995* (Ries et al., 1999) summarized the current knowledge on the established causes of selected childhood cancers as follows:

Acute lymphoblastic leukemia (ALL): Known risk factors are male; age 2 to 5 years; white race; higher socioeconomic status; diagnostic or therapeutic radiation exposure during the prenatal or postnatal periods; and selected genetic conditions (Down's syndrome, neurofibromatosis, Shwachman syndrome, Bloom syndrome, ataxia telangiectasia, Langerhaus cell histiocytosis and Klinefelter syndrome). "With the exception of prenatal exposure to x-rays and specific genetic syndromes, little is known about the causes of childhood ALL" (Ries et al., 1999).

Acute myeloid leukemia (AML): Known risk factors are Hispanic ethnicity; prenatal diagnostic radiation exposure; and selected genetic conditions (Down's syndrome, neurofibromatosis, Shwachman syndrome, Bloom syndrome, familial monosomy 7, Kostmann granulocytopenia, and Fanconi anemia). "Different risk factors are emerging for childhood AML that distinguish the disease from ALL, and this may provide avenues for future epidemiological studies" (Ries et al., 1999).

Central nervous system (CNS) tumors: More than 90% of all CNS tumors in children are located within the brain. Known risk factors are male; therapeutic doses of ionizing radiation to the head; selected genetic conditions including neurofibromatosis, tuberous sclerosis, nevoid basal cell syndrome, Turcot syndrome, and Li-Fraumeni syndrome. "Unfortunately, the causes of CNS cancer remain largely undetermined." "There is no specific risk factor that explains a substantial proportion of brain tumor occurrence, but there are a couple of factors that explain a small proportion" (Ries et al., 1999).

Sympathetic nervous system tumors: "Relatively little is known about the etiology of sympathetic nervous system tumors" (Ries et al., 1999).

The following brief review focuses on categories of childhood cancer risk factors that have been published in the scientific literature. More extensive information on these risk factors may be found in the following comprehensive reviews: Ries et al., 1999; Little, 1999; McBride, 1998; Sandler and Ross, 1997; Chow et al., 1996; Pritchard-Jones, 1996; Zahm and Devesa, 1995; Ross et al., 1994; and Kuijten and Bunin, 1993.

Demographic, Pregnancy and Birth Characteristics: Studies of the relationship between socioeconomic status and childhood cancer have generally found that while children of higher socioeconomic class are at increased risk for leukemia, the relationship between socioeconomic status and other childhood cancers is inconclusive (Chow et al., 1996). Some studies have reported a positive association of older maternal age (age $30 or 35 at birth) with childhood leukemia (Hemminki et al., 1999, Buckley et al., 1994), while other studies have found a weak association (Westergaard et al., 1997) or no association (Kaatsch et al., 1998; Shu et al., 1988; Shaw et al., 1984). A positive association of older paternal age with childhood brain cancer was found in a large Swedish study (Hemminki et al., 1999). Data on the relationship between birth order and birth weight with childhood brain cancer and leukemia are contradictory (Yeazel et al., 1997; Westergaard et al., 1997; Forsberg and Källén, 1990; Kaatsch et al., 1998; Eisenberg and Sorahan, 1987; Cnattingius et al., 1995; Emerson et al., 1991; Daling et al., 1984; Robison et al., 1987; Chow et al., 1996).

Family Medical History: Some studies have found increased occurrence of cancer in relatives of children with leukemia and brain cancer, indicating possible familial genetic susceptibility to cancer or a common shared environmental exposure, but other studies have not found this positive association (Farwell and Flannery, 1984; Kuijten et al., 1993; Gold et al., 1994; Kuijten et al., 1990; Olsen et al., 1995; Mosso et al., 1999; Bondy et al., 1991; Chow et al., 1996).

A large Danish cohort study of adults with autoimmune diseases found a statistically significant excess of childhood lymphoma, and a non-significant excess of childhood leukemia among their offspring when compared with the general childhood population of Denmark (Mellemkjær et al., 2000).

Data on maternal history of miscarriage or stillbirth and childhood cancer are contradictory, with some studies finding a positive association (Emerson et al., 1991; Kaye et al., 1991; van Steensel-Moll et al., 1985), while other studies have reported a negative or protective association (Kuijten et al., 1990; Bunin et al., 1994), or no association (Linet et al., 1996; Kaatsch et al.,1998; Shu et al., 1988; Cnattingius et al., 1995).

An association between childhood cancers and history of birth defects in relatives have been found in some studies (Gold et al., 1994; Kuijten and Bunin, 1993).

For the more common childhood cancer types, known heritable factors do not appear to play a strong causal role in most children with cancer, but the identification of such factors remains an active area of research. For two rarer childhood cancer types (retinoblastoma and Wilms' tumor), heritable factors have been identified as important risk factors. Certain genetic syndromes (Down's syndrome, Bloom syndrome, neurofibromatosis, Li-Fraumeni syndrome, ataxia telangiectasia, Shwachman syndrome, Langerhaus cell histiocytosis, Klinefelter syndrome, familial monosomy 7, Kostmann granulocytopenia, Fanconi anemia, tuberous sclerosis, nevoid basal cell syndrome, and Turcot syndrome) increase the risk of childhood leukemia and/or brain cancer (Ries et al., 1999).

Health, Medical Conditions and Procedures: Children with birth defects, particularly Down's syndrome, have been shown to be at increased risk of developing childhood cancer (Mili et al., 1993a; Mili et al., 1993b).

While prenatal exposure to medications may be associated with increased childhood cancer risk, there is contradictory or insufficient evidence that any substances other than diethylstilbestrol (DES) are definite risk factors. Maternal use of DES during pregnancy was found to be associated with a risk of rare vaginal adenocarcinomas in the daughters (Herbst et al., 1971). Prenatal use of metronidazole (used to treat protozoal and anaerobic infections) was not found to be associated with childhood cancer (Thapa et al., 1998). Barbiturate use (during pregnancy and childhood) and maternal use of anti-nausea medication have been associated with increased risk of childhood cancers in some studies, but not in others (Kuijten and Bunin, 1993). Positive associations between childhood barbiturate exposures and brain tumors are especially difficult to interpret because these medications may be used to treat early manifestations of disease. Findings on the association of neonatal vitamin K administration and childhood cancer are contradictory with some studies reporting positive findings (Golding et al., 1992), while subsequent reports found an absence of any association or a weak association (Passmore et al., 1998; Parker et al., 1998; McKinney et al., 1998; Klebanoff et al., 1993).

While neonatal infections were reported to be associated with childhood brain tumors in a Swedish case-control study (Linet et al., 1996), a study of infectious diseases during the first year of life failed to show any association with childhood leukemia in a Dutch case-control study (van Steensel-Moll et al., 1986).

Ionizing radiation given for therapeutic purposes during childhood prior to the 1970s has been documented to be associated with increased risk of nervous system tumors, thyroid cancer, and leukemia (Modan et al., 1974; Ron et al., 1988; Ries et al., 1999; Little, 1999). Risk from diagnostic and therapeutic radiation has been substantially decreased in the past few decades because of lower radiation doses, better shielding, and less frequent use of x-rays during pregnancy. A large German case-control study failed to find any association between childhood cancers and postnatal X-rays during the years 1975 to 1994 (Meinert et al., 1999). Some studies have reported an increased risk of childhood cancers after prenatal x-ray exposure (Zahm and Devesa, 1995; Harvey et al., 1985; Mole, 1990; Rodvall et al., 1990; Shu et al., 1994). This finding was not confirmed in other studies (Meinert et al., 1999).

Diagnostic maternal ultrasound during pregnancy was reported in one study to be associated with childhood cancer in a small subset of children who died from cancer after age six (Kinner-Wilson and Waterhouse, 1984) but subsequent studies have not found any association (Shu et al., 1994; Bunin et al., 1994; McCredie et al., 1994a).

Head trauma has been associated with childhood brain cancer (Gurney et al., 1996b; Howe et al.,1989), though this association has not been found in other studies (Kuijten et al., 1990; McCredie et al, 1994b).

Dietary Factors: Breast feeding has been reported in some studies to decrease the risk of childhood acute leukemia and Hodgkin's disease, though other studies have not supported these findings (Shu et al., 1999; Davis, 1998; Shu et al., 1995).

N-nitroso precursor compounds, which are found in cured meats, induce brain tumors in experimental animals. Consumption of cured or processed meats by the child or by the mother during pregnancy has been associated in some studies, but not in others, with increased risk of childhood brain cancer or leukemias (Blot et al., 1999; Preston-Martin et al., 1996c; Peters et al., 1994; Sarasua and Savitz, 1994; Bunin et al., 1993; Kuijten et al., 1990; McCredie et al., 1994a).

Use of multivitamins and high consumption of fruits and vegetables during pregnancy have been reported to reduce the risk of childhood brain tumors (Preston-Martin et al., 1998; McCredie et al., 1994a; Bunin et al., 1993). Consumption of aspartame (an artificial sweetener) has not been found to be associated with childhood brain cancer (Gurney et al., 1997).

***Tobacco Smoke and Alcohol Use*:** In general, the association between exposure to parental tobacco smoking and cancer in children seems to be weak or absent (Boffetta et al., 2000; Klebanoff et al., 1996; Pershagen et al.,1992). Studies have found little evidence that parental smoking is a risk factor for childhood brain cancer (Linet et al., 1996; Norman et al., 1996; Gold et al., 1993; Kuijten et al., 1990) or neuroblastoma (Yang et al., 2000). Maternal smoking during pregnancy has not been found to increase the risk of leukemia in children (Little, 1999; Kaatsch et al., 1998; Shu et al., 1996; Klebanoff et al., 1996; Zahm and Devesa, 1995; Severson et al., 1993). However, paternal smoking during the preconception period was found in two studies to be associated with the risk of childhood leukemia (Ji et al., 1997; Shu et al., 1996). Other studies have not found an association between paternal smoking and childhood leukemia (Kaatsch et al., 1998; Severson et al., 1993; Shu et al., 1988).

Maternal alcohol consumption has been associated with certain forms of myeloid leukemia (Severson et al., 1993; and Shu et al., 1996).

Household-related Exposures: Chemicals, Animals and Electromagnetic Fields (EMFs): Increased risk of childhood brain tumors, leukemias, and non-Hodgkin's lymphoma has been reported in relation to household pesticide use and parental agricultural occupations. While no specific chemical has been identified as a risk factor, studies have identified usage of pesticides, insecticides, termiticides, pest strips, flea collars, flea/tick products, and herbicides as possible concerns (Meinert et al., 2000; Zahm and Ward, 1998; Pogoda and Preston-Martin, 1997; Daniels et al., 1997).

There has been considerable speculation regarding possible viral causes of childhood cancers, particularly leukemias, but there is no epidemiologic evidence suggesting risk related to specific organisms. Increased risk of childhood cancer has been observed among children in contact with farm animals, and presumably, animal viruses (Holly et al., 1998; Bunin et al., 1994). Greaves (1988) has suggested that leukemias may result from spontaneous mutation in B-cells and subsequent proliferation in response to an infectious agent. Kinlen (1991) has theorized that mixing of previously isolated populations may increase childhood leukemia risk due to introduction of unidentified infectious agents.

Increased risk of childhood leukemia, brain cancer, or other childhood cancers has been found in some studies of exposure to residential electromagnetic fields (Wertheimer and Leeper, 1979; Savitz et al., 1988; NRC, 1997; NIEHS, 1998; Meinert and Michaelis, 1996). However, several recent large-scale studies have shown small to no increases in risk (UK Childhood Cancer Study Investigators, 1999; Linet et al., 1997; Preston-Martin et al., 1996b; Gurney et al., 1996a; McBride et al., 1999). Leukemia and brain cancer incidence has also been associated in some studies with prenatal and postnatal use of electric blankets or heated water beds, while in other studies no association has been found (Preston-Martin et al., 1996a; Gurney et al., 1996a; Hatch et al., 1998; London et al.,1991; Savitz et al., 1990). A working group report by the National Institute of Environmental Health Sciences concluded that there is limited evidence that residential exposure to extremely low frequency magnetic fields is carcinogenic to children, and that there is inadequate evidence with respect to childhood nervous system tumors and childhood lymphomas (NIEHS, 1998). The inconsistency of findings among the studies on residential electromagnetic fields, and uncertainty as to the proper way to measure exposure, makes the interpretation of this body of literature difficult and inconclusive.

Incident cases of childhood leukemia and brain cancer were not found to be associated with residential proximity to radio or television transmitters (Dolk et al., 1997).

Environmental Exposure to Air or Water Contamination: Several studies have reported significant associations between childhood cancers, particularly leukemia, and residential proximity to high traffic density (Savitz and Feingold, 1989; Feychting et al., 1998; Pearson et al., 2000) but these results have not been confirmed in other studies (Harrison et al., 1999). While benzene, a known cause of leukemia in adults, is a component of vehicle exhaust, it is unclear if these findings are due to exposure to vehicle exhaust or some other factor (Pearson et al., 2000).

A British research group has reported that birth residences of children who died from cancer were geographically associated with a variety of industrial sites that emitted petroleum-derived volatile chemicals; furnace or kiln smoke and gases; or internal combustion engines (Knox and Gilman, 1997; Knox and Gilman, 1998).

Studies in Woburn, Massachusetts have examined the relationship between contaminated drinking water and childhood leukemia (Lagakos et al., 1986; Massachusetts Department of Public Health, 1997). Community water supplies in Woburn contained elevated levels of trichloroethylene, tetrachloroethylene and other industrial chemicals. The Massachusetts Department of Public Health study concluded that the incidence of childhood leukemia was associated with the mothers' potential for exposure to water from the contaminated wells, particularly for exposure during pregnancy. However, these findings should be interpreted with caution since the small number of study subjects led to imprecise estimates of risk. A study by the New Jersey Department of Health found that rates of leukemias and non-Hodgkin's lymphomas in adults and children were elevated in towns with a history of trichloroethylene-contaminated drinking water, compared to towns without such contamination (Cohn et al., 1994).

Parental Occupation and Childhood Cancer: A large variety of parental occupational exposures have been reported in the scientific literature to be associated with various childhood cancers. Four comprehensive reviews on parental occupational exposures and risk of childhood cancer have been published since 1985: Colt and Blair, 1998; O'Leary et al., 1991; Savitz and Chen, 1990; and Arundel and Kinnier-Wilson, 1986. The strongest evidence of risk for childhood leukemia appears to be for paternal exposure to solvents, paints/ pigments, pesticides, petroleum products, or paternal employment in motor vehicle-related occupations. For childhood nervous system cancers, the strongest evidence of risk appears to be for paternal exposure to paints/pigments, solvents or chemicals (Colt and Blair, 1998;

O'Leary et al., 1991). Studies on maternal occupations suggest a possible association between employment in personal services and textiles occupations with childhood leukemia (Colt and Blair, 1998). Parental occupational exposures have been hypothesized to potentially contribute to childhood cancer through a variety of circumstances and time periods: maternal or paternal exposures prior to conception (germ cell effects); during pregnancy (tranplacentally through direct maternal workplace exposure or through substances inadvertently transferred to the home by either parent); and after birth (through breast feeding or through direct exposure to substances inadvertently carried home by either parent) (Colt and Blair, 1998).

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Appendix C: Geocoding Methods

Introduction

To conduct exposure assessments for drinking water sources, air point sources, and proximity to sites of concern, it was necessary to first position the study residences on an electronic map file and to assign geographical coordinates to each residence (i.e., latitude and longitude). The assignment of latitude and longitude coordinates (geocoding) was performed by using geographic information system (GIS) software, paper maps, and information provided during interviews or extracted from birth certificates. All geocoding was performed by staff blinded to the case or control status of each study address.

Geocoding Procedures

All Ocean County study residences were included in the geocoding step. Ocean County was considered a large enough area to capture all significant air exposures for the air point source assessments and encompassed all exposure routes associated with the other environmental assessments.

Using dBase 5.0 for Windows (Borland International Corporation, 1994), a database was developed for all study residences located in Ocean County. Geocoding of these addresses was first performed using ArcView version 3.1 software (Environmental Systems Research Institute Incorporated, 1996) and Tiger5 base maps (Cypress Geo-Resources Incorporated, 1997). Latitude and longitude coordinates were assigned to each residence in the batch mode, using the address-matching default settings of ArcView. AtlasGIS (Strategic Mapping Incorporated, 1992) was used to geocode addresses that were not located with ArcView. Matching in AtlasGIS was also originally preformed in the batch mode, and later performed in the interactive mode, as described below.

The batch modes of ArcView and AtlasGIS were successful in address-matching the majority of study residences. Unsuccessful geocoding of addresses in batch-mode was due to missing or incorrect information in the Tiger5 base maps or problems specific to our residential data base including missing street numbers, misspelled street names, or apartment complex names listed in place of street names.

To correct these residential address issues, paper maps and phone books were examined to correct misspellings, locate streets not in the Tiger5 base map files, and identify the street addresses of apartment complexes. Interview books were reviewed for anecdotal information that could assist in identifying residence location, such as nearby cross streets or landmarks (schools, post offices, etc.). In addition, personnel from the Ocean County Board of Taxation, Dover Township Engineering Department, and the United States Postal Service were queried in an attempt to clarify remaining issues.

Study residences that could be geocoded with GIS software were assigned latitude and longitude coordinates corresponding to the appropriate location on the electronic street map (to the fifth decimal point). Addresses that were interactively geocoded were assigned latitude and longitude coordinates on the appropriate street segment, as long as the location could be narrowed to within one-quarter mile. Addresses that still could not be geocoded (insufficient address information to narrow the location to within one-quarter mile) were assigned a code for unknown location.

Geocoding Results

Tables C1and C2 present the geocode success for the study addresses by case and control status. Both the Interview Study and Birth Records Study cases had slightly higher batch mode success rate than controls (73.3 and 89.6 vs. 72.4 and 81.0). Very few residences in either the Interview Study and Birth Records Study had insufficient address information for geocoding (6 vs. 3).

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Strategic Mapping Incorporated: Atlas GIS, Santa Clara, California, 1992.

Tables

Table C1. Interview Study Summary of Address Geocode Success

Geocode Characteristic	Cases		Controls	
	Number	Percent	Number	Percent
Ocean County addresses to be geocoded	75		272	
Addresses geocoded using automated program (batch mode)	55	73.3	197	72.4
Addresses geocoded interactively:				
Complete addresses, but Tiger file missing needed information	7		35	
Incomplete addresses	11		36	
Subtotal	18	24.0	71	26.1
Addresses not geocoded due to insufficient information	2	2.7	4	1.5

Table C2. Birth Records Study Summary of Address Geocode Success

Geocode Characteristic	Cases		Controls	
	Number	Percent	Number	Percent
Ocean County addresses to be geocoded	48		483	
Addresses geocoded using automated program (batch mode)	43	89.6	391	81.0
Addresses geocoded interactively:				
Complete addresses, but Tiger file missing needed information	2		55	
Incomplete addresses	3		34	
Subtotal	5	10.4	89	18.4
Addresses not geocoded due to insufficient information	0	0.0	3	0.6

Appendix D: Drinking Water Source Assessment

Introduction

Evidence of recent (1996) and historical contamination of the public drinking water system in Dover Township has been previously documented (NJDHSS and ATSDR, 2001a; NJDHSS and ATSDR, 2001b; NJDHSS, NJDEP and ATSDR, 2001). Consequently, as part of this epidemiological investigation, it was important to examine the relationship between sources of drinking water and incidence of childhood cancers in Dover Township. Private well usage in Dover Township areas and public water usage by well field source within the United Water Toms River water system were taken into account for this assessment. To evaluate the public well field component of the assessment, the federal Agency for Toxic Substances and Disease Registry (ATSDR) developed a computerized water distribution model of the 1998 system, conducted calibration and validation analyses of the 1998 model (ATSDR, 2000), and developed annual historical water distribution system models through the study period, 1962 through 1996 (ATSDR, 2001). All development and utilization of water distribution modeling were conducted by researchers blinded to the case or control status of study residences.

All household tap water in Dover Township is solely derived from groundwater, whether delivered to the residence by the pubic water system or from a private residential well. The public water distribution system has expanded its residential service in the area over the past 40 years, by using groundwater from a variety of well fields throughout the community. Currently, 85-90% of the homes in Dover Township are supplied with public water from public supply well fields, while 10-15% use a private residential well for their potable water supply (ATSDR, 2000). Over the study period, there is documented evidence that contamination in the groundwater impacted both the public water system and private wells in some areas within Dover Township.

Public Water Quality

In the mid 1960s, water from three of the shallow wells in the Holly Street well field were reported to have a distinct odor and tinted color due to contaminants (Toms River Water Company, 1965). The water in one well was chlorinated to reduce coloration. In 1966, analyses of the water revealed the presence of diazotizables and nitrobenzene (Toms River Chemical Company, 1966). One of these wells was sealed in 1967, another well was used until 1975, and the third well was used until 1980 (NJDHSS and ASTSDR, 2001a; NJDHSS, NJDEP and ATSDR, 2001). The Holly Street well field is located near the Toms River approximately 1.4 miles downstream of the Ciba-Geigy facility. Ciba-Geigy's practice of discharging chemical waste directly into the Toms River in the years prior to 1966 and the type of chemical contaminants detected in the public well water (diazotizables and nitrobenzene) indicate that Ciba-Geigy was the probable source of the pollution at the Holly Street well field.

In 1986, volatile organic compounds (VOCs) were detected in some of the wells of the Parkway well field. Air-strippers were placed on these wells in 1988 in order to remove contaminants. Air stripping is a treatment method that removes VOCs from contaminated water by forcing an airstream through the water to evaporate the contaminants. Subsequently, it was determined that the contaminated groundwater plume from the Reich Farm Superfund Site was being drawn to the Parkway well field and impacted the water quality at the well field (Malcolm Pirnie, 1992; NJDHSS and ATSDR, 2001b). However, since the only targeted chemicals that were detected were VOCs, it was decided that air stripping would be sufficient to remove the contaminants and meet federal and state drinking water standards. (Targeted chemicals are chemicals that are on the Priority Pollutant List, Hazardous Substances List, and/or the New Jersey State Safe Drinking Water List).

In 1996, non-target semi-volatile chemicals were detected in the Parkway well field water (NJDHSS, NJDEP and ATSDR, 2001). Due to their semi-volatile nature, these contaminants were not being removed from the water through air stripping and were distributed to the community through the public drinking water distribution system. Immediately following the discovery in 1996 of the non-targeted contaminants, the two impacted Parkway wells were disconnected from the water distribution system. The water from two additional wells nearest the Reich Farm groundwater plume are currently being treated by activated carbon filtration and continue to be used for potable purposes.

The non-target semi-volatile chemicals in the Reich Farm groundwater plume belong to a group of chemicals referred to as styrene-acrylonitrile trimer. Waste from styrene-acrylonitrile polymer production processes were deposited at the Reich Farm Superfund site (NJDHSS and ATSDR, 2001b). The illegal dumping of over 4,500 drums of chemical waste at the Reich Farm site occurred in 1971. Most of the drums and contaminated soil were removed in 1972. In 1974, an additional 51 drums and 1,100 cubic yards of soil were also removed. The Reich Farm Superfund Site is located approximately one mile north of the Parkway well field. The time it took for contaminants from the Reich Farm site to reach the Parkway well field has not been clearly established, though a recent model predicts a travel time of approximately 10 to 15 years (Sykes, 1999). However, the Union Carbide Corporation and the NJDEP continue to refine the groundwater models estimating transit time.

Groundwater Regions

Groundwater pollution, particularly due to VOC contamination, has been detected in some areas of Dover Township. Some of these areas were impacted with contaminants from hazardous sites, such as Ciba-Geigy (NUS, 1988; ATSDR, 1988; NJDHSS and ATSDR, 2001a), Reich Farm (NJDEP, 1974; Ebasco, 1988; NJDHSS and ATSDR, 2001b), and the Dover Township Municipal Landfill (NJDEP, 1990; NJDHSS and ATSDR, 2001c). Other contaminated groundwater areas in Dover

Township cannot be attributed to a specific pollutant source. Usually, when groundwater contaminants are detected in an area, private wells in that area are sealed and public water mains are extended to supply residences and businesses with potable public water.

Information used to select and delineate the groundwater regions was derived from a number of sources, including: published reports on environmental assessments in Dover Township; New Jersey Department of Environmental Protection files and staff communications, notably from the Bureau of Groundwater Pollution Abatement and the New Jersey Geological Survey; and records and communication with Ocean County government officials, primarily the Ocean County Health Department and Planning Commission.

Ten groundwater regions of known VOC contamination were identified and their borders defined. In addition, an eleventh region of street segments, where at least one private well was found to contain VOCs above their respective Maximum Contaminant Level (MCL), was identified. An MCL is a federal and/or state standard for the maximum permissible level of a contaminant in water delivered to any user of a public water system. Figure D1 presents the locations of the groundwater regions. Appendix E lists all street sections located in each groundwater region.

C Region A, the Pleasant Plains Zone I region, is located in the western portion of Dover Township. This zone was identified in 1974, as an area that was likely to have been impacted by Reich Farm. Subsequent testing demonstrated that only a portion of the groundwater in this region was actually impacted by the Reich Farm plume. Groundwater in this region did contain elevated concentrations of total organic chemicals and total organic carbon (NJDEP, 1974).

C Region B overlays the groundwater contamination plume from the Reich Farm Superfund Site. The groundwater plume contains both VOCs and the styrene-acrylonitrile isomer (NJDHSS and ATSDR 2001b; Malcom Pirnie, 1993).

C Region C represents two plumes that both originate at the Ciba-Geigy site.

One plume is located in the primary Cohansey aquifer and travels predominately west toward the Toms River. The second plume is in the lower Cohansey aquifer and travels predominately northwest toward the Toms River. Residential wells west of Ciba-Geigy were found to contain VOCs at concentrations above their respective MCL, including chloroform, benzene, trichloroethylene (TCE), and tetrachloroethylene (PCE) (NUS, 1988). Residential wells north of Ciba-Geigy were found to contain lead and mercury, but Ciba-Geigy was not believed to be the source of this contamination (NJDHSS and ATSDR, 2001a).

C Region D is the Silverton groundwater region located in the northeast corner of Dover Township. In 1982, private wells in the area were found to contain VOCs. Compounds detected included 1,2 dichloroethane, chloroform, carbon tetrachloride, TCE, trichloroethane, and benzene (NJDHSS and ATSDR, 2001c).

C Region E, the Silverton Road groundwater region, is located in the north-central portion of Dover Township. Because of its proximity to the Dover Township Municipal Landfill and the types of contaminants found, this region is thought to be impacted by the Landfill (NJDEP, 1990; NJDHSS and ATSDR, 2001c). Contaminants detected in this region included benzene, PCE, and lead.

C Region F is known as the North Gilford Park groundwater region and is located in the East Dover section of Dover Township. In 1987 and 1988, TCE and PCE were detected in private wells above their respective MCL.

C Region G, the Shelter Cove groundwater region, is located in the eastern side of Dover Township, near Goose Creek and Shelter Cove. In 1986, PCE, TCE, and 1,2-dichloroethene were detected at concentrations above their respective MCL. The contaminants may have originated at a dry cleaners on Fischer Avenue.

C Region H, the Breton Harbors groundwater region, is located in the southern part of Dover Township, adjacent to Island Heights Boro. In 1988, private wells in the area were found to contain VOCs above their respective MCL.

C Region I, the North Maple Avenue groundwater region, is located in the northwestern corner of Dover Township. Prior to 1986, wells in the area were found to contain benzene, TCE, 1,2-dichloroethene, and mercury at concentrations above their respective MCL.

C Region J, the Beachwood and Veeder groundwater region, is located in the southeastern portion of Dover Township, close to Goose Creek. In 1997, wells in this area were found to contain TCE, PCE, and mercury at concentrations above their respective MCL.

C Region K contains street segments that were identified as having at least one well with a confirmed detection of a VOC above an MCL. Region K includes portions of Sica Lane, Alfred Lane, Annette Lane, Parkwood Avenue, Elizabeth Avenue, McKinley Avenue, Buermann Avenue, Beachview Drive, Waldron Road, Gary Road, River Terrace, Gem Terrace, Sunray Drive, and Susan Street.

These groundwater regions were digitized onto an ArcView GIS map file. All Interview Study residences with self-reported use of a private well in Dover Township were geocoded (see Appendix C for geocoding methods) and placed on the ArcView GIS map file. Birth Records Study residences were assumed to be connected to the public water system unless no public distribution pipe was located near the residence during the year the subject lived in the residence. These Birth Records Study residences were assumed to use a private well and placed on the ArcView GIS map file. Residences that were located within a groundwater region were identified and coded for the assessment of groundwater source.

Public Water Source

The purpose of this activity was to estimate the proportion of water delivered monthly to each study residence over time from each of the multiple well field sources within the United Water Toms River (UWTR) distribution system. ATSDR was the lead agency in developing a model for the public water source assignment. The major elements of this activity include:

1) development of a computerized distribution model of the 1998 public water distribution system;

2) field-data collection of the 1998 system operations;

3) calibration and validation analyses of the 1998 model based on the field-data;

4) development of annual historic distribution system models through the study period, 1962 through 1996; and

5) historic model reconstruction of water flow within the public system and assignment of the monthly proportion of water delivered from each public well field source to each study residence connected to the public system.

The UWTR distribution system grew rapidly during the study period. In the early part of the study period, the UWTR system had two well fields supplying all its water and mostly served just the Toms River section of Dover Township. The 1998 system supplied water to over 85,000 residents through an interconnected distribution system which derives source water from eight separate "points of entry" (well field sources). The UWTR system currently serves most of the mainland area of Dover Township, all of South Toms River, and part of Berkeley Township. The growth of the water distribution system was largely due to the need to serve the expanding population in Dover Township. In addition, the public water system expanded into areas where private wells were found to be contaminated.

1998 Distribution Model: The purpose of creating a computer model of the 1998 distribution system was to simulate the flow of water through the system based on the behavior of the hydraulic system, as closely as possible, in terms of its spatial and temporal characteristics. ATSDR selected the EPANET computer model to accomplish this activity (Rossman, 1994; ATSDR, 2000). EPANET is public domain software, developed by the United States Environmental Protection Agency, that is capable of simulating the percent of water reaching select locations in a water distribution system network from a specified source (i.e., point of entry or well field).

The first step in the development of the 1998 distribution model was to collect structural information on the 1998 water system in order to develop an electronic distribution system map. The electronic map of the system included all distribution pipes greater than two inches in diameter, wells, points of entry into the system, storage tanks, and booster pumps. The map of the 1998 system contained 488.2 miles of pipes (16,071 pipe segments or links), three elevated and six ground-level storage tanks, 23 groundwater wells in eight well fields, and 12 booster pumps. Within the model, each pipe was adjusted for length, diameter, and roughness. The roughness coefficient was based on the material used for the pipe and the age of the pipe (ATSDR, 2000). Additionally, ATSDR assigned an elevation, demand (consumption) value, and demand pattern at junctions of pipe segments (termed nodes) in the water distribution system. A total of 14,987 nodes were represented in the 1998 distribution model.

In order to accurately calibrate the flow of water through the 1998 system model, field-data were collected on the UWTR system operation for two separate time periods, March and August 1998. The purpose for collection of UWTR field-data was to obtain present-day measurements to accurately characterize the system in order to calibrate and subsequently validate the model's predictive capability (ATSDR, 2000). The model was calibrated to the hydraulic and operational data collected during March 1998. The model was then validated against the data collected during August 1998. These two field-data collection periods were selected because they represent the two typical water demand patterns for the UWTR system: a winter demand pattern occurring from October through mid-May and a peak demand pattern occurring during the summer.

During each of the two field-data collection periods, 48 hours of water pressure data were gathered simultaneously at 25 UWTR system hydrants using continuous pressure recording data loggers. Data on storage tank water levels, system demand, and pump and well status were also obtained. Hydrant locations were selected to provide thorough, system-wide coverage so that effects from storage tanks filling or emptying, and pumps turning on or off could be characterized by pressure changes at these hydrants (ATSDR, 2000).

Calibration of the 1998 distribution model entailed adjusting the model parameters until an acceptable match was achieved between the measured March 1998 data and model simulated values, including pressures at test hydrants, water levels in storage tanks, flows from pumps, and pumpage from groundwater wells. A pressure difference at the test hydrant locations (differences between measured and simulated) of ±5 pounds per square inch (psi) to ±7.5 psi was selected as the calibration criteria for the model. The absolute pressure difference of the March-measured hourly average pressure data and the simulated values for all hydrant locations ranged from 1.4 psi to 5.3 psi with 90% of the hourly differences being 5.0 psi or less (ATSDR, 2000). The results of this analysis indicate that the 1998 distribution model is reasonably calibrated to the March 1998 field-data.

The calibrated 1998 distribution model was then rerun to derive simulated values for comparison with the August 1998 field-data. This simulation was a validation step to evaluate the 1998 model's ability to accurately derive pressure estimates under different operating conditions. The comparison of the new simulated values to the actual August field-data provide evidence as to the model's predictive capability. The results of this simulation indicate that the absolute pressure difference of the measured hourly average pressure data to the simulated values for all hydrant locations ranged from 2.9 psi to 6.6 psi with 90% of the hourly differences being 7.5 psi or less. The validation results support the assertion that the model is calibrated and an acceptable and reliable representation of the UWTR water distribution system during 1998.

As further evidence of the reliability of the model calibration, a simulation of the transport of barium, a naturally occurring constituent of groundwater, was conducted and compared with data collected in March and April 1996 (NJDHSS, NJDEP, and ATSDR, 2001) at 21 schools and six points of entry into the UWTR distribution system. The difference between the measured and simulated barium concentrations ranged from 0.6%-25.6% with an average relative difference of 13.6%. Further analyses indicated the model produced a slight under-prediction with a high correlation between the measured and simulated values. This provides additional support that the model is reasonably calibrated and an acceptable representation of the 1998 distribution system.

Historic Model Reconstruction: With a calibrated and validated current model of the UWTR water distribution system, the next step was to develop historic, annual (1962 through 1996) maps and models of the system. To reconstruct each of the annual historic maps, ATSDR removed pipes, wells, well fields, tanks, and pumps from the 1998 distribution system model that were not in use or available during a particular year. Annual pipeline installation records for the historic reconstruction were supplied by UWTR. Historic data on wells and on their monthly pumping volumes were collected from utility operator reports submitted to the New Jersey Department of Environmental Protection.

Systems operation over time needed to be considered for the historic models. UWTR provided ATSDR with daily system operations information for the years 1978 to 1996. However, prior to 1978 daily system operating rules needed to be developed. Model assumptions for the daily system operation prior to 1978 included: wells could only be turned on or off when an operator was present in the control room (6am to 10pm daily) with the exception of wells that were known to operate automatically; wells ran continuously rather than turning on and off multiple times a day; tanks were not allowed to drain or fill completely; booster pumps and ground-level storage tanks were not used for simulations; and sufficient water pressure needed to be maintained throughout the distribution system at all times for adequate fire protection (ATSDR, 2001).

Each of the 35 historic annual models was rerun 12 times per year, incorporating operating rules and well field pumping volume data. Monthly historic model simulations were run for each well field in use in the water distribution system for each of the 420 months during the years 1962 through 1996. For each historic model simulation, the flow of water from each point of entry (well field source) through the UWTR system was simulated by the EPANET software.

NJDHSS provided ATSDR with a geocoded electronic file of all study residences (see Volume IV, Appendix C for geocoding methods) to be used during the annual historic modeling. Using the 1998 current map of the water distribution system, ATSDR manually assigned a node identification number (nearest appropriate up-gradient node) to each residence in the database file. If a node did not exist near the residence, then that residence was not provided a node identification number or considered connected to the public water distribution system. Each node represents a junction of pipe segments within the distribution system. All NJDHSS and ATSDR staff performing geocoding and determination of node assignment were blinded to the case or control status of the home's residents.

The proportion of water delivered to a specific location (node) from each of the distribution system's well field sources was estimated. The total monthly proportion from each well field source to each node and associated residence was designed to sum to 100 percent. The proportion of well field water delivered to each connected study residence by month was calculated, saved in electronic files, and supplied to NJDHSS. It is important to note that the term "study residence" as used in Tables D1 through D5 are actually study homes but do not necessarily reflect the true time a study subject resided in the home.

Summary of Water Source Output Data

The number of study residences potentially connected to the United Water Toms River drinking water distribution system increased gradually and consistently throughout the 1960s, 1970s, and 1980s, as demonstrated by Table D1. This increase may be due to a number of factors, including the expansion of the water pipelines into areas formerly served exclusively by private wells and the building of new homes and/or roads in formerly rural areas. The number of potential study residences connected to the water distribution system was essentially stable in the 1990s.

Annual Water Distribution Patterns: Table D1 also presents the average annual relative contributions by well field to each study residence assigned to public water; monthly ranges of the average relative contributions; and the season in which each well field had the highest average relative contribution.

During the study interval, the well field with the highest annual relative contribution changed three times. From 1962 to 1966, the Brookside well field was the major production well field, with an average relative contribution of 77.2% in 1962 and declining to a relative contribution of 55.3% in 1966. From 1967 to1973, the Holly Street well field was the major production well field, contributing on average greater than 50% of all water to study residences. From 1974 until 1996, the Parkway well field was the major production well field, contributing approximately 40-60% of the water (with the exception of 1988, when some of the Parkway wells were taken off-line for the installation of an air stripper).

While there were differences observed between average relative contributions from year to year, the major annual differences in contiguous years were associated with the increased use of a particular well field. For example, the annual relative contribution pattern changed when production from the Parkway well field increased beginning in 1973 and 1974, becoming the major production well field through the end of the study period. This is also demonstrated when production from the Berkeley well field was increased in 1988. Other annual differences were due to well fields being taken off line for repair or work. For example, in late 1987 and early 1988, Parkway production decreased while an air stripper was installed on some of its wells.

Seasonal Variations in Distribution Patterns: Seasonal variation in relative contributions were observed in every year. Some well fields supplied water year-round, while other well fields were used only in the peak season (Summer) months to supplement production. Figures D2 and D3 demonstrate some of the seasonal patterns observed. In 1965 (Figure D2), and in general from 1962 to 1966 (Figure D3), water from the Holly Street well field was used to supplement water from the Brookside well field during the peak season. In 1978 (Figure D2), and in general from 1974 to 1981 (Figure D3), water from the Brookside and other well fields was used to supplement water from the Parkway and Holly Street well fields during the peak season. In 1988 (Figure D2), the Holly Street well field was the major production well field in the off-season and the Parkway well field was the major production well in the peak season. In 1992 (Figure D2), and in general from 1990 to 1996 (Figure D3), water from the Holly Street well field was used to supplement water from the Parkway well field during the peak season. Some of the smaller well fields were only used during the peak season.

Relative Contributions by Well Field at Four Study Residences in Different Sections of Dover Township: Average annual relative water contributions from the well field sources to four separate study residences in different sections of Dover Township are presented in Tables D2 through D5. These tables demonstrate annual differences in the distribution of water by well field to an individual residence, as well as the variation of relative well field contributions to different areas of Dover Township. The major well field suppliers for the residence in West Dover (Table D2) were Holly Street in 1965 and 1970, Indian Head in 1978, and Berkeley in 1988 and 1996. The major well field suppliers for the residence in East Dover (Table D3) were Brookside in 1965 and Holly Street in 1970, 1978, 1988, and 1996. The major well field suppliers for the residence in Central Dover (Table D4) were Brookside in 1965, Holly Street in 1970, 1988, and 1996, and Parkway in 1978. The major well field suppliers for the residence in Northeast

Dover (Table D4) were Brookside in 1965 and 1970 and Parkway in 1978, 1988, and 1996.

Seasonal variation at these four study residences is presented in Figure D4 for the years 1977 through 1979. The seasonal variation is particularly evident in the East Dover and Northeast Dover residence locations. The East Dover residence was primarily supplied by the Holly Street well field. This water was supplemented with water from the Brookside well field during the peak months. The Northeast Dover location was primarily supplied with water from the Parkway well field. This water was supplemented with water from a local well field, Silver Bay, during the peak months. There was less of a seasonal influence in the water distribution at the West Dover and Central Dover residences.

Drinking Water Indices

Drinking water source indices were developed for ten public well field sources of the UWTR water distribution system and eleven groundwater areas in Dover Township (Regions A through K). The ten public well fields constitute all points of entry for water entering the UWTR system for the study period 1962 to 1996. Information available in the Interview Study included parental history of the following issues:

1) type of drinking water (public system or private well) each residence received from one year prior to birth to the year of diagnosis;

2) residential conversion from a private well to a public system during occupancy;

3) primary water for cooking and drinking in each residence (household tap, bottled water or both);

4) use of a water softening or other household water treatment system in each residence; and

5) the number of drinks (glasses per day) with household tap water consumed

by the mother prior to the child's birth and by the child after birth. No information on residential drinking water source or consumption was available for the Birth Records Study.

In addition to the water source indices, the Interview Study utilized the water consumption information in order to create additional drinking water exposure variables, known as the water source/consumption indices, which combined the water consumption data and the previously derived water source indices. Information on use of bottled water and use of water treatment systems within the home was examined.

Water Source Indices: Each drinking water source index was calculated as the arithmetic average of the monthly percentage of water received at all residences lived in by the child (or mother prior to birth) over a specified life time period. For Interview Study residences within the UWTR system, the monthly well field source percentages were derived from ATSDR water distribution modeling. Each child's month and year (from one year prior to birth until the month of diagnosis) were matched to the appropriate month and year of the model percentage output. For residences outside the UWTR delivery area or identified as using a private residential well, the contribution for each well field source was given a zero monthly value during the appropriate month(s) of residence.

All Dover Township Interview Study residences identified as using a private well were evaluated to determine if the residence was located within each groundwater region. Residences located within a groundwater region were given monthly values of 100 for that specific region during the time period the child lived in the residence. A monthly water source value of zero was assigned to groundwater regions for the following situations: residences which used a private well not within that groundwater region; residences connected to the UWTR system; and residences outside of Dover Township.

In the Interview Study, separate water source indices were calculated for each of the ten well field sources and eleven groundwater regions over three specific time periods: the child's entire study time period (one year prior to birth until the month of case diagnosis); the pregnancy time period (nine months prior to birth); and the postnatal period (the birth month until the month of case diagnosis). Each of the indices were then categorized into three levels (none/low, medium and high) using several alternate approaches. The first approach was a tertile cut point of three equal groups. The second approach was a low (0%), medium (greater than 0% to 49.9%), and high (50+%) cut point distribution. The final approach was a none/low (<10%), medium (10% to 49.9%), and high (50+%) cut point distribution.

Since birth certificates, which provided the residential information in the Birth Records Study, provide no information on whether a residence receives public or private water, these residences were assumed to be connected to the UWTR system unless water distribution pipes were not located near the residence during the year of the child's birth, as determined by ATSDR's annual water distribution models. Each drinking water source index was calculated as the arithmetic average of the monthly percentage of water received at the birth residence over a nine month period (eight months prior to birth plus the birth month). The monthly well field source percentages were derived from ATSDR water distribution modeling. Each of the child's nine study months were matched to the appropriate month and year of the model percentage output.

Birth Records Study residences considered not connected to the UWTR system were given a zero value for the contribution of each well field source for each of the child's nine pregnancy months. These residences were then evaluated for location within each groundwater region. Residences located within a groundwater region were given a value of 100 for that region (and a zero for all other regions) in each of the child's nine months. Residences not located in any region were given zeros in all regions.

Separate water source indices for the Birth Records Study were calculated for each well field source and groundwater region. Each of these indices were then categorized into three categories (none/low, medium and high) in a similar manner as in the Interview Study.

Water Source/Consumption Indices: Water source/consumption indices were created in order to analyze the water source and water consumption data in the Interview Study. The water source/consumption indices combined the water source categories discussed above with the water consumption tertile categories. The merging of these two categorical variables created a water source/consumption category rating (shown in Table D6). If the water source index for source A was categorized as low, the water source/consumption index was also categorized as low, regardless of amount consumed. If the water source index for source A was categorized as medium, the water source/consumption index was also be categorized as medium, unless water consumption was high (in which case the water source/consumption index was rated as high). If the water source index for source A was categorized as high, the water source/consumption index was also categorized as high, unless water consumption was low (in which case the water source/consumption index was rated as medium).

The water source/consumption indices were developed in an asymmetric fashion in order to account for non-ingestion pathways of exposure. Weighting of the water source/consumption indices toward the water source categories permitted exposure independent of the ingestion route to be taken into account. The water source/consumption indices were analyzed for the pregnancy and postnatal periods only.

An alternative method was also used to create water source/consumption indices. The alternative method to derive the second water source/consumption indices used continuous data for both the water source (as a percent of water delivered to the home) and water consumption (average number of glasses of water consumed per day). The two continuous variables were multiplied together resulting in a new continuous variable. The new variable was then categorized into exposure categories (non/low, medium, and high) based on the tertile distribution of the control data. The alternative water source/consumption indices were analyzed for the pregnancy and postnatal periods only.

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Tables

Table D1. Relative Contributions from Well Field Sources to Study Residences Assigned to Public Water

Year and (Number of residences assigned)	Well Field Source	Percent Annual Average Relative Contribution	Percent Range of Monthly Relative Contributions	Season with Highest Relative Contribution
1962	Brookside	77.2	66.8 - 95.0	Winter
(n = 187)	Holly Street	22.8	5.0 - 33.2	Summer
1963	Brookside	74.5	61.8 - 83.9	Winter
(n = 216)	Holly Street	25.5	16.1 - 38.2	Summer
1964	Brookside	65.9	58.5 - 72.8	Winter
(n = 250)	Holly Street	34.1	27.2 - 41.5	Summer
1965	Brookside	62.9	51.0 - 74.2	Winter
(n = 306)	Holly Street	37.1	25.8 - 49.0	Summer
1966	Brookside	55.3	36.9 - 74.5	Winter
(n = 316)	Holly Street	42.3	25.5 - 58.6	Summer
	South Toms River	1.9	0 - 7.3	Summer
	Anchorage	0.4	0 - 3.8	Summer
	Silver Bay	0.1	0 - 0.8	Summer
1967	Holly Street	51.9	41.8 - 58.3	Fall
(n = 330)	Brookside	39.7	23.8 - 54.0	Winter
	Indian Head	6.8	0 - 18.5	Summer
	South Toms River	1.3	0.1 - 3.8	Summer
	Anchorage	0.1	0 - 1.5	Spring
	Silver Bay	0.1	0 - 1.3	Spring
1968	Holly Street	60.4	46.5 - 68.7	Summer
(n = 342)	Brookside	31.5	20.1 - 40.7	Winter
	Indian Head	6.6	1.9 - 10.7	Summer
	South Toms River	1.4	0.4 - 2.6	Winter
	Silver Bay	<0.1	0 - 0.8	Spring
	Anchorage	<0.1	0 - 0.4	Spring

Year and (Number of residences assigned)	Well Field Source	Percent Annual Average Relative Contribution	Percent Range of Monthly Relative Contributions	Season with Highest Relative Contribution
1969	Holly Street	67.0	62.2 - 72.4	Spring
(n = 370)	Brookside	26.2	16.1 - 33.4	Winter
	Indian Head	4.5	2.5 - 8.1	Summer
	South Toms River	1.5	0.1 - 2.6	Winter
	Silver Bay	0.5	0 - 2.5	Spring
	Anchorage	0.2	0 - 1.7	Spring
1970	Holly Street	63.9	60.2 - 68.0	Fall
(n = 417)	Brookside	27.8	20.3 - 35.1	Winter
	Indian Head	3.7	0.2 - 5.5	Spring
	Silver Bay	2.1	0 - 8.5	Summer
	South Toms River	2.0	0.4 - 3.8	Spring
	Anchorage	0.5	0 - 2.4	Summer
1971	Holly Street	60.5	51.8 - 67.0	Spring
(n = 446)	Brookside	24.5	16.1 - 34.0	Fall
	Indian Head	4.9	1.3 - 12.1	Fall
	Silver Bay	3.8	0 - 9.0	Summer
	Anchorage	2.6	0 - 8.2	Summer
	Parkway	2.3	0 - 16.9	Summer
	South Toms River	1.4	0 - 3.5	Winter
1972	Holly Street	58.5	38.8 - 71.5	Fall
(n = 463)	Brookside	25.0	21.2 - 32.3	Winter
	Indian Head	6.0	2.0 - 10.6	Winter
	Parkway	4.2	0 - 22.7	Summer
	Silver Bay	2.4	0 - 5.9	Summer
	Anchorage	2.4	0 - 6.0	Summer
	South Toms River	1.4	0 - 3.6	Summer

Year and (Number of residences assigned)	Well Field Source	Percent Annual Average Relative Contribution	Percent Range of Monthly Relative Contributions	Season with Highest Relative Contribution
1973	Holly Street	58.8	37.9 - 71.3	Winter
(n = 487)	Brookside	15.4	0.4 - 26.4	Winter
	Parkway	12.6	0 - 32.5	Fall
	Indian Head	8.1	2.4 - 15.9	Fall
	South Toms River	2.3	0.1 - 4.2	Fall
	Silver Bay	1.7	0 - 6.1	Summer
	Anchorage	1.1	0 - 4.5	Summer
1974	Parkway	38.9	28.7 - 61.2	Winter
(n = 506)	Holly Street	35.6	27.9 - 56.3	Winter
	Indian Head	16.3	2.5 - 29.5	Fall
	South Toms River	3.3	0.5 - 4.5	Spring
	Brookside	2.5	0 - 7.2	Summer
	Silver Bay	1.8	0 - 6.1	Summer
	Anchorage	1.6	0 - 5.2	Summer
1975	Parkway	40.3	30.2 - 46.0	Winter
(n = 528)	Holly Street	33.4	27.2 - 42.0	Fall
	Indian Head	14.2	7.9 - 20.8	Winter
	Brookside	8.4	0 - 21.4	Summer
	South Toms River	2.8	1.2 - 4.1	Winter
	Anchorage	0.5	0 - 2.5	Summer
	Silver Bay	0.5	0 - 2.5	Spring
1976	Parkway	41.1	25.6 - 48.0	Winter
(n = 541)	Holly Street	33.3	21.7 - 44.4	Fall
	Indian Head	11.2	5.5 - 19.9	Fall
	Brookside	7.6	0 - 19.8	Summer
	South Toms River	2.4	1.6 - 3.5	Spring
	Silver Bay	2.3	0 - 6.9	Summer
	Anchorage	2.1	0 - 5.0	Spring

Year and (Number of residences assigned)	Well Field Source	Percent Annual Average Relative Contribution	Percent Range of Monthly Relative Contributions	Season with Highest Relative Contribution
1977	Parkway	45.3	28.2 - 64.2	Winter
(n = 548)	Holly Street	29.8	22.3 - 38.6	Fall
	Indian Head	10.0	4.7 - 14.3	Fall
	Brookside	9.4	0 - 22.4	Summer
	Silver Bay	2.0	0 - 6.1	Summer
	South Toms River	1.8	0 - 4.8	Fall
	Anchorage	1.5	0 - 4.9	Summer
1978	Parkway	46.1	35.2 - 66.3	Winter
(n = 555)	Holly Street	29.2	21.6 - 39.1	Fall
	Brookside	9.5	0 - 19.4	Summer
	Indian Head	8.2	0 - 12.7	Winter
	Anchorage	2.5	0 - 5.8	Spring
	South Toms River	2.3	0.2 - 3.4	Spring
	Silver Bay	2.3	0 - 6.4	Summer
1979	Parkway	57.1	46.0 - 66.0	Spring
(n = 581)	Holly Street	26.6	20.6 - 37.8	Fall
	Indian Head	8.3	3.7 - 13.0	Fall
	Brookside	5.3	0 - 16.3	Summer
	South Toms River	1.5	0.8 - 3.0	Winter
	Silver Bay	0.9	0 - 5.4	Summer
	Anchorage	0.2	0 - 2.1	Spring
1980	Parkway	59.8	47.5 - 69.1	Winter
(n = 582)	Holly Street	16.9	0 - 23.9	Spring
	Indian Head	7.4	3.5 - 10.6	Winter
	Route 70	6.7	0 - 21.6	Fall
	Brookside	6.6	0 - 19.6	Summer
	South Toms River	1.3	0.8 - 2.4	Fall
	Anchorage	0.8	0 - 4.8	Summer
	Silver Bay	0.6	0 - 4.2	Summer

Year and (Number of residences assigned)	Well Field Source	Percent Annual Average Relative Contribution	Percent Range of Monthly Relative Contributions	Season with Highest Relative Contribution
1981	Parkway	60.9	36.9 - 72.0	Winter
(n = 583)	Route 70	17.7	10.4 - 23.8	Winter
	Holly Street	6.9	0 - 35.4	Summer
	Indian Head	6.7	4.0 - 9.3	Winter
	Brookside	5.7	0 - 16.4	Summer
	South Toms River	2.0	0.7 - 3.6	Fall
	Anchorage	< 0.1	0 - 0.2	Summer
1982	Parkway	48.9	22.4 - 74.8	Winter
(n = 589)	Holly Street	27.2	0 - 52.1	Fall
	Route 70	14.9	9.8 - 22.1	Winter
	Indian Head	6.4	4.0 - 9.2	Winter
	South Toms River	2.2	1.5 - 3.4	Summer
	Brookside	0.3	0 - 3.4	Spring
1983	Parkway	53.9	33.6 - 78.1	Fall
(n = 593)	Holly Street	24.7	0 - 48.7	Spring
	Route 70	11.7	6.9 - 18.6	Winter
	Indian Head	4.6	0.9 - 7.4	Winter
	South Toms River	3.3	1.3 - 8.5	Spring
	Brookside	1.8	0 - 9.0	Summer
1984	Parkway	54.7	29.4 - 77.9	Winter
(n = 607)	Holly Street	23.1	0 - 48.2	Fall
	Route 70	12.4	7.7 - 14.7	Winter
	Indian Head	5.7	3.5 - 7.2	Fall
	Brookside	2.0	0 - 12.1	Summer
	South Toms River	2.0	0.5 - 5.0	Spring
	Anchorage	0.1	0 - 0.9	Spring
1985	Parkway	50.3	40.1 - 76.4	Fall

Year and (Number of residences assigned)	Well Field Source	Percent Annual Average Relative Contribution	Percent Range of Monthly Relative Contributions	Season with Highest Relative Contribution
(n = 622)	Holly Street	32.9	3.6 - 46.0	Summer
	Route 70	9.9	6.7 - 12.9	Winter
	Indian Head	3.7	0 - 5.8	Spring
	South Toms River	2.9	1.8 - 4.5	Summer
	Brookside	0.3	0 - 3.3	Summer
1986	Parkway	47.5	32.9 - 78.3	Winter
(n = 647)	Holly Street	31.7	0 - 44.4	Fall
	Route 70	9.6	1.5 - 14.3	Fall
	Indian Head	6.1	3.7 - 9.2	Fall
	South Toms River	3.5	1.1 - 9.2	Spring
	Brookside	1.3	0 - 5.3	Spring
	Berkeley	0.2	0 - 1.7	Summer
1987	Parkway	44.0	12.1 - 71.8	Winter
(n = 673)	Holly Street	31.9	0 - 58.8	Summer
	Route 70	9.8	6.4 - 13.6	Winter
	Indian Head	8.3	0.1 - 14.8	Winter
	South Toms River	2.5	<0.1 - 6.1	Winter
	Brookside	2.4	0 - 16.4	Fall
	Berkeley	1.1	0.1 - 5.1	Summer
1988	Holly Street	32.4	0 - 48.6	Winter
(n = 697)	Parkway	31.0	17.8 - 61.9	Fall
	Berkeley	12.2	3.0 - 22.7	Winter
	Route 70	9.1	4.5 - 11.9	Winter
	Brookside	8.4	0 - 17.0	Spring
	Indian Head	3.9	0 - 11.6	Fall
	South Toms River	3.0	1.0 - 6.7	Summer
1989	Parkway	46.6	26.7 - 73.1	Winter

Year and (Number of residences assigned)	Well Field Source	Percent Annual Average Relative Contribution	Percent Range of Monthly Relative Contributions	Season with Highest Relative Contribution
(n = 703)	Holly Street	26.6	0 - 53.3	Fall
	Berkeley	11.2	2.9 - 20.1	Winter
	Route 70	8.5	5.8 - 12.3	Winter
	Indian Head	3.7	0 - 8.2	Summer
	South Toms River	2.5	0.3 - 4.4	Summer
	Brookside	0.6	0 - 2.8	Summer
1990	Parkway	46.7	31.2 - 62.8	Winter
(n = 710)	Holly Street	18.4	0 - 45.5	Summer
	Berkeley	13.9	5.3 - 23.9	Fall
	Route 70	9.3	5.5 - 12.2	Winter
	Indian Head	7.8	4.4 - 12.0	Winter
	South Toms River	2.4	1.1 - 4.7	Summer
	Brookside	1.4	0 - 7.6	Summer
1991	Parkway	44.2	29.6 - 58.8	Winter
(n = 710)	Holly Street	26.2	0 - 46.4	Summer
	Berkeley	11.5	3.2 - 23.9	Fall
	Route 70	7.6	0.3 - 11.8	Fall
	Indian Head	4.7	2.8 - 9.1	Winter
	South Toms River	3.0	1.0 - 5.4	Summer
	Brookside	2.8	0 - 8.1	Summer
	Windsor	0.1	0 - 0.3	Summer
1992	Parkway	39.0	24.4 - 58.5	Winter
(n = 711)	Holly Street	27.0	0 - 47.9	Summer
	Berkeley	13.3	2.5 - 27.1	Winter
	Route 70	8.3	5.0 - 10.9	Winter
	Brookside	4.7	0 - 14.0	Summer
	Indian Head	4.2	1.5 - 5.9	Winter
	South Toms River	2.7	0.6 - 6.7	Fall
	Windsor	0.7	0 - 4.5	Summer
1993	Parkway	44.6	23.8 - 63.2	Winter

Year and (Number of residences assigned)	Well Field Source	Percent Annual Average Relative Contribution	Percent Range of Monthly Relative Contributions	Season with Highest Relative Contribution
(n = 712)	Holly Street	20.9	0 - 43.6	Summer
	Berkeley	10.5	0.8 - 29.0	Fall
	Route 70	5.5	2.0 - 8.1	Winter
	Indian Head	5.3	1.9 - 9.8	Fall
	South Toms River	5.1	0.7 - 12.5	Winter
	Windsor	4.5	0 - 24.7	Summer
	Brookside	3.5	0 - 11.1	Summer
1994	Parkway	47.4	28.9 - 60.1	Fall
(n = 713)	Berkeley	18.0	2.6 - 30.7	Fall
	Holly Street	10.2	0 - 36.4	Summer
	South Toms River	7.2	2.5 - 14.1	Winter
	Indian Head	5.6	0 - 9.9	Winter
	Route 70	4.8	2.4 - 6.9	Winter
	Brookside	4.0	0 - 15.5	Spring
	Windsor	2.7	0 - 14.6	Summer
1995	Parkway	48.3	29.6 - 63.5	Winter
(n = 713)	Berkeley	16.8	1.9 - 28.6	Fall
	Holly Street	16.3	0 - 39.7	Summer
	Indian Head	6.1	2.2 - 9.7	Winter
	South Toms River	4.7	0 - 9.7	Summer
	Route 70	3.9	1.7 - 6.1	Winter
	Windsor	2.7	0 - 15.8	Summer
	Brookside	1.2	0 - 5.9	Summer
1996	Parkway	41.1	0 - 72.2	Winter
(n = 714)	Holly Street	25.7	0 - 46.4	Spring
	Berkeley	11.7	1.8 - 27.5	Fall
	Windsor	11.4	0 - 46.1	Fall
	South Toms River	4.3	0 - 8.8	Summer
	Route 70	3.0	0.5 - 5.1	Winter
	Indian Head	2.4	0 - 9.6	Winter
	Brookside	0.3	0 - 2.0	Spring

Table D2. Average Annual Relative Contribution from Well Field Sources to

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Study Residence in West Dover During Select Years

Well Field	1965 (%)	1970 (%)	1978 (%)	1988 (%)	1996 (%)
Parkway	-	-	40	3	9
Holly Street	95	100	17	8	18
Brookside	5	0	0	0	0
Berkeley	-	-	-	86	73
Windsor	-	-	-	-	0
Indian Head	-	0	43	2	<1
Route 70	-	-	-	0	0
South Toms River	-	0	0	0	0
Silver Bay	-	0	0	-	-
Anchorage	-	0	0	-	-

Table D3. Average Annual Relative Contribution from Well Field Sources to a

Study Residence in East Dover During Select Years

Well Field	1965 (%)	1970 (%)	1978 (%)	1988 (%)	1996 (%)
Parkway	-	-	12	9	17
Holly Street	7	75	66	61	35
Brookside	93	16	13	14	0
Berkeley	-	-	-	7	11
Windsor	-	-	-	-	24
Indian Head	-	0	1	1	1
Route 70	-	-	-	<1	0
South Toms River	-	9	8	7	12
Silver Bay	-	0	0	-	-
Anchorage	-	0	0	-	-

Table D4. Average Annual Relative Contribution from Well Field Sources to a Study Residence in Central Dover During Select Years

Well Field	1965 (%)	1970 (%)	1978 (%)	1988 (%)	1996 (%)
Parkway	-	-	82	18	42
Holly Street	26	100	16	73	44
Brookside	74	0	0	0	0
Berkeley	-	-	-	6	6
Windsor	-	-	-	-	0
Indian Head	-	0	2	3	2
Route 70	-	-	-	1	0
South Toms River	-	0	0	0	1
Silver Bay	-	0	0	-	-
Anchorage	-	0	0	-	-

Table D5. Average Annual Relative Contribution from Well Field Sources to a Study Residence in Northeast Dover During Select Years

Well Field	1965 (%)	1970 (%)	1978 (%)	1988 (%)	1996 (%)
Parkway	-	-	50	46	64
Holly Street	<1	22	4	4	11
Brookside	100	43	5	5	1
Berkeley	-	-	-	5	3
Windsor	-	-	-	-	7
Indian Head	-	13	3	9	5
Route 70	-	-	-	32	9
South Toms River	-	0	<1	0	1
Silver Bay	-	21	26	-	-
Anchorage	-	1	11	-	-

Table D6. Water Source/Consumption Rating Scheme.

Water Consumption Category	Water Source (A) Index Category		
	None/Low	Medium	High
None/Low	Low	Medium	Medium
Medium	Low	Medium	High
High	Low	High	High

Figures

Figure D1. Groundwater Source Regions

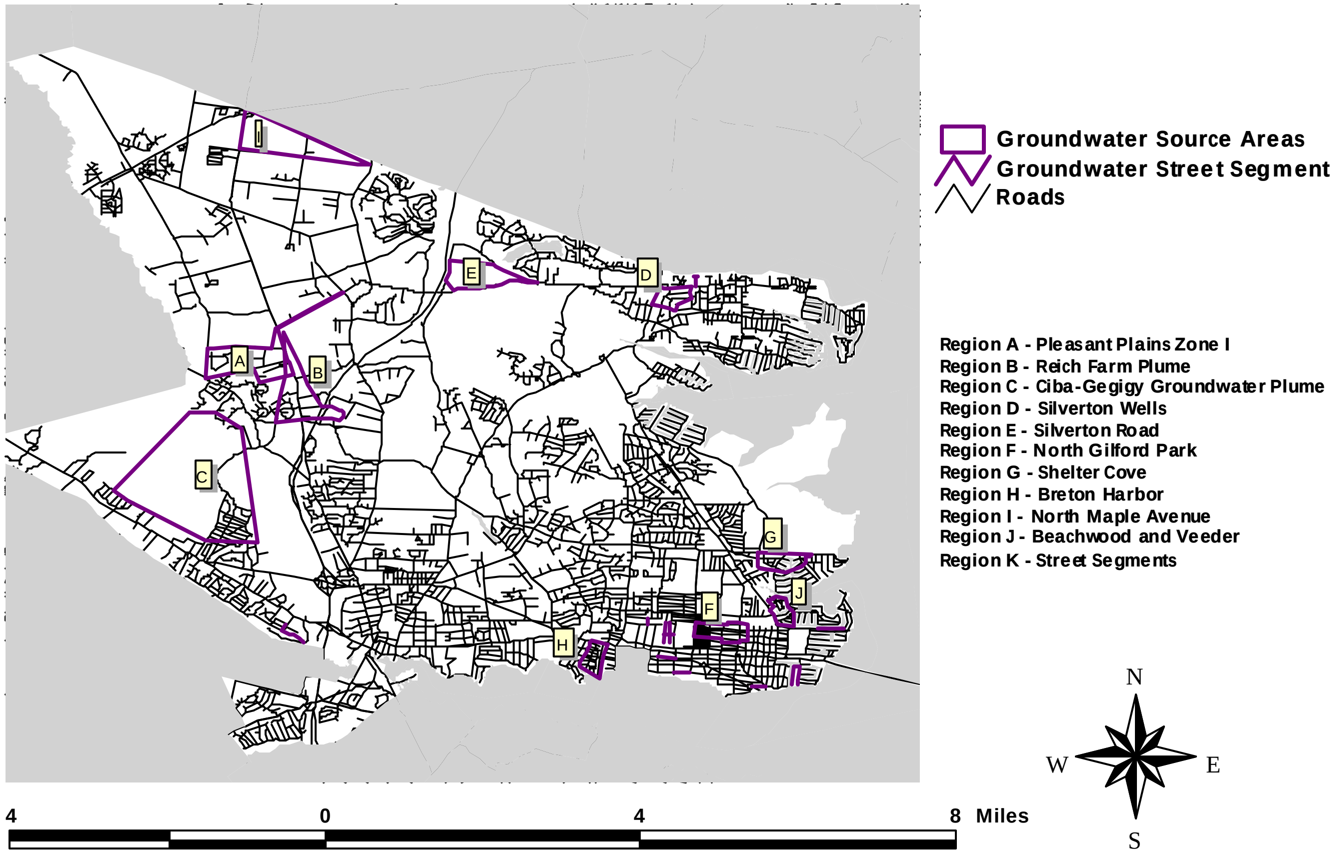


Figure D2. Average Monthly Relative Well Field Source Contribution to all Potentially Connected Study Residences During Four Sample Years

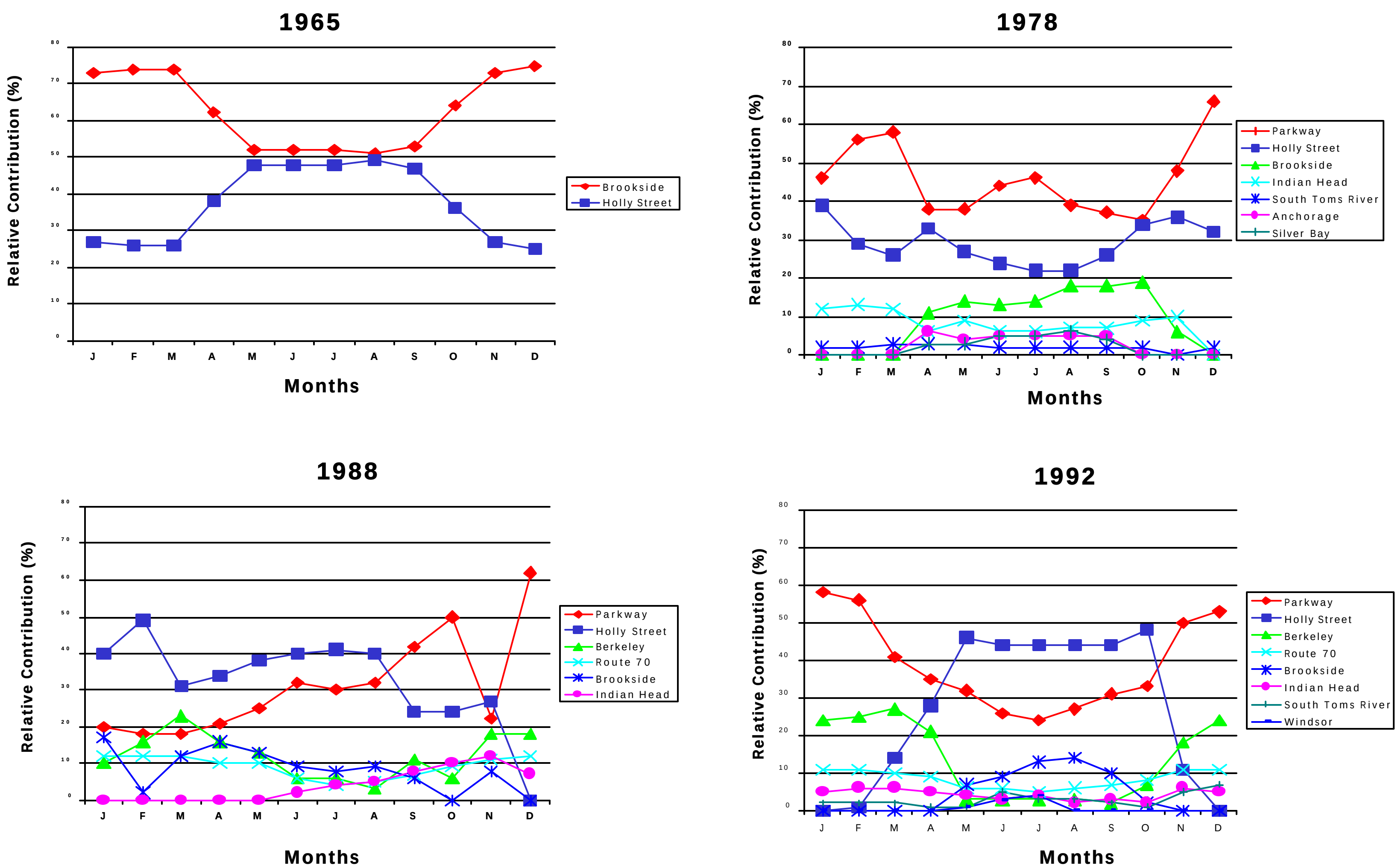
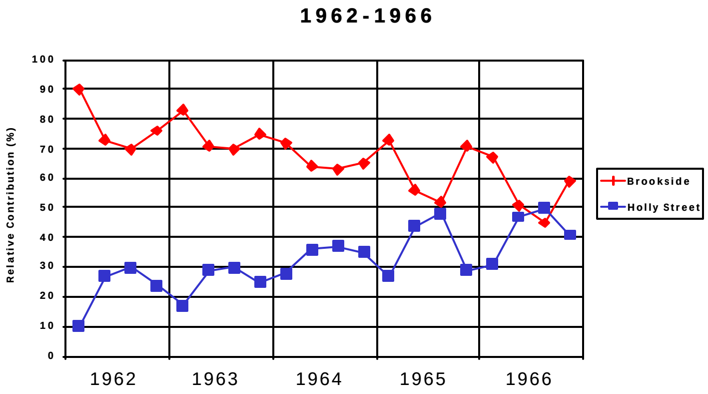
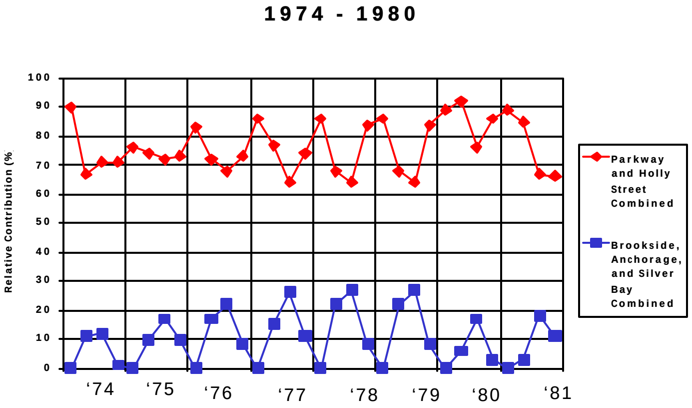


Figure D3. Average Seasonal Relative Well Field Source Contributions to All Potentially Connected Study Residences During Three Time Intervals





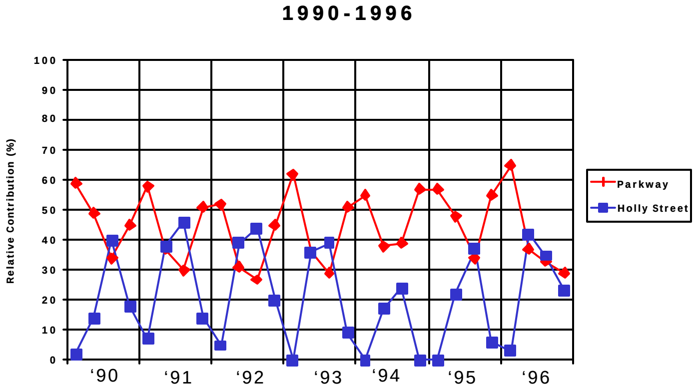
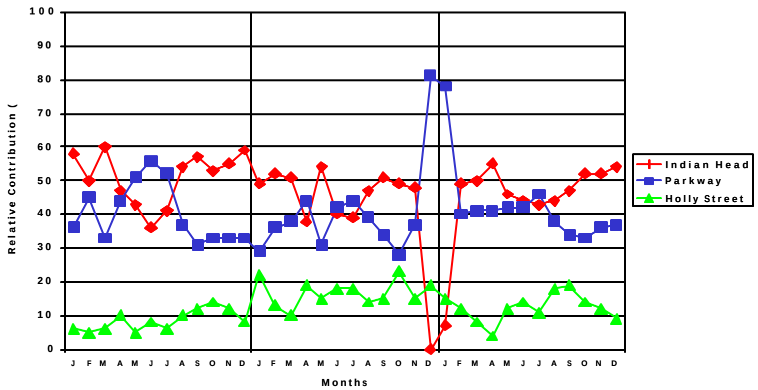
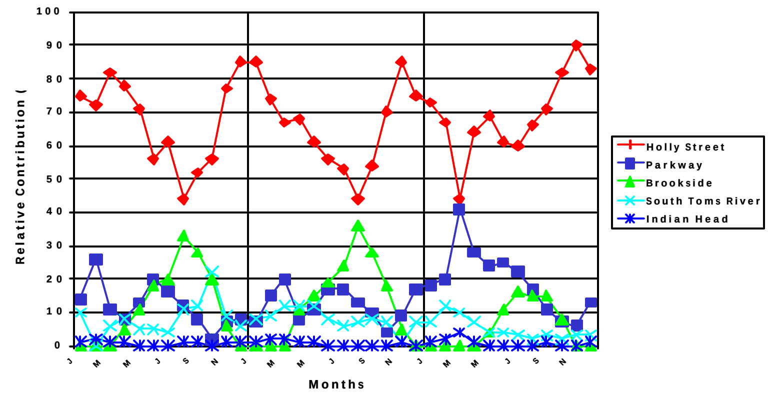


Figure D4. Monthly Relative Well Field Source Contribution to Four Study Residences in Different Sections of Dover Township (1977-1979)

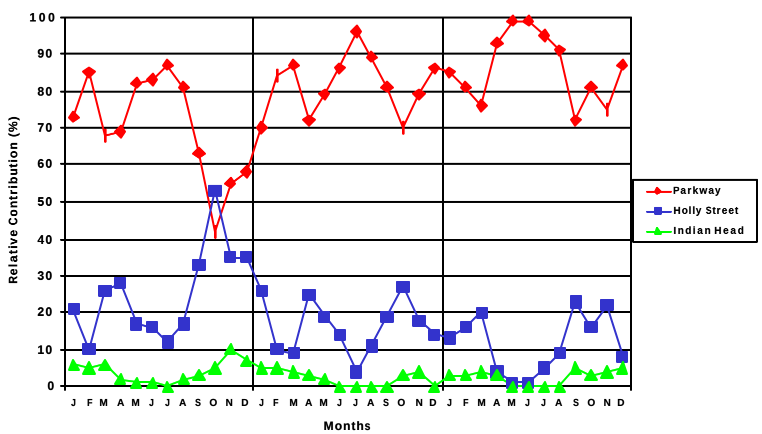
West Dover



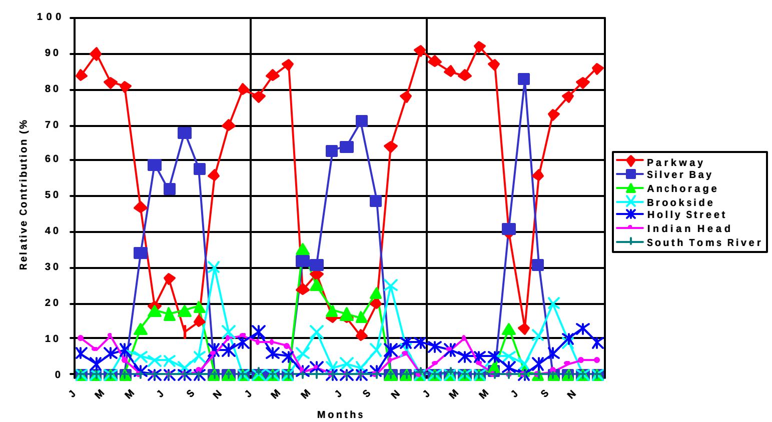
East Dover



Central Dover



Northeast Dover



Appendix E: Listing of Streets by Groundwater Region

Region A: The Pleasant Plains Zone 1 groundwater area.

Ashford Road
Buxton Road
Caroline Lane
Church Road, west of Old Freehold Road
Clayton Avenue
Fritz Drive
Lavenham Court
Lakewood Road, from Silverton Road to Monroe Avenue
Menlow Court
Monroe Avenue
Sunset Avenue
Webster Road
Weston Drive
Wicklow Court

Region B: The Reich Farm Plume groundwater area.

Bamberry Lane, between Lakewood Road and Green Drive
Clayton Avenue, just west of Lakewood Road
Dugan Lane, part way from Lakewood Road to Wallach Drive
Froriep Lane
Green Drive
Indian Head Road, north side between Lakewood Road and Green Drive
Lakewood Road, between Sunset Avenue and Indian Head Road
Monroe Avenue, just west of Lakewood Road
Raymond Avenue, between Lakewood Road and Ark Street
Swain Avenue
Sunflower Lane, between Ark Street and Green Drive
Sylvan Court
Webster Road, just west of Lakewood Road
Whitty Road, just east of Lakewood Road

Region C: The Ciba-Geigy Groundwater Plume area.

Cadillac Drive
Cardinal Drive, north of Winding River Drive
Cliffside Drive
Dell Avenue, north side west of Cedar Hill Lane
Irving Place, north side
Hummingbird Lane
Jordan Drive
Leaward Avenue, between Waldo Court and Shoshone Court
Morningside Drive
Oak Leaf Lane
Oak Ridge Parkway, between Pine Fork Drive and Coulter Street
Oakside Drive, north of Morningside Drive
Pine Fork Drive, west of Oak Ridge Parkway
Shady Nook Drive, Cardinal Drive to just west of Oakside Drive
Shoshone Court
Sun Valley Road
Waldo Court
Woodridge Avenue

Region D: The Silverton groundwater area.

Beechtree Drive, between Mount Lane and Kettle Creek Road
Dogwood Lane
Hawthorne Place
Kettle Creek Road, south side between Larch Drive and Beechtree Drive
Larch Drive, between Oak Hill Drive and Kettle Creek Road
Mount Lane, between Beechtree Drive and Oak Hill Drive
Oak Hill Drive, north side between Larch Drive and Mount Lane

Region E: The Silverton Road groundwater area.

Church Road, between the North Bay Avenue and Silverton Road
North Bay Avenue, between Church Road and Twinbrook creek
Silverton Road, between Church Road and Twinbrook creek

Region F: The North Gilford Park groundwater area.

Bradley Boulevard, north or Driscoll Road
Dolly Road
Dorothy Road

Driscoll Road
Halsey Road
Harding Avenue, north of 3rd Avenue
Garfield Avenue, between 3rd Avenue and South Street
Leahy Road
Roosevelt Avenue, north of 4th Avenue
Taylor Road
4th Avenue, between Harding Avenue and Martin Road
5th Avenue
6th Avenue, between Roosevelt Avenue and Martin Road
7th Avenue

Region G: The Shelter Cove groundwater area.

Anegada Avenue
Bay Avenue, between Tunney Point Drive and Nassau Drive
Cuelbra Avenue
Linda Drive
Midwood Drive
Simmons Drive
Simot Lane
Stanley Drive, east of Tunney Point Drive
St.Johns Avenue
Tunney Point Drive

Region H: The Breton Harbors groundwater area.

Breton Harbors Drive
Gladney Avenue
Main Bayway
Poe Avenue
River Drive, south of Highway 37
Route 37, south side only between Tennyson Avenue and River Drive
Tennyson Avenue, east side only
Whittier Avenue, between Tennyson Avenue and River Drive
1st Bayway
2nd Bayway
3rd Bayway
4th Bayway
5th Bayway

6th Bayway
7th Bayway
8th Bayway
9th Bayway
10th Bayway

Region I: The North Maple Avenue groundwater area.

Lakewood Road, north of North Maple Avenue to Lakewood Township
North Maple Avenue
Owen Court
Tapestry Court
Vermont Avenue, north of North Maple Avenue to Lakewood Township

Region J: The Beachwood and Veeder groundwater area.

Beachwood Avenue, from Creek Road to just north of Veeder Avenue
Creek Road
Driftwood Place
Elliccot Avenue, east side from John Street to just north of Veeder Avenue
Fischer Boulevard, east side between John Street and Oceanic Drive
Goose Place
John Street
Oceanic Drive, between Sterling Street and Fischer Boulevard
Veeder Avenue, east of Elliot Avenue
Windsor Avenue, between Sterling Street and Fischer Boulevard
Wood Street, northern half of street just south of Oceanic Drive

Region K: Miscellaneous street segments located in several sections of Dover Township.

Miscellaneous streets in the southeastern section include:

Alfred Lane, south of Mary Lane
Annette Lane
Beachview Drive, between Churchill Drive and just east of Marshall Road
Buermann Avenue, between Berkeley Avenue and of Gouverneur Avenue
Elizabeth Avenue, between Gouverneur Avenue and Coolidge Avenue
Gary Road, between Cruiser Court and Bay Shore Drive
McKinley Avenue, east of Sheridan Avenue
Parkwood Avenue, between Mohawk Drive and Shady Lane
Sica Lane, south of Mary Lane
Waldron Road

Miscellaneous streets in the southwestern section include:

River Terrace, between Edgewood Drive and Gem Terrace
Gem Terrace, between Cahill Road and River Terrace

Miscellaneous streets in the northeastern section include:

Sunray Drive
Susan Street, connected to Sunray Drive

Appendix F: Point Source Air Pollution Assessment

Introduction

In order to account for the potential exposure to industrial air pollution in the Dover Township area, the New Jersey Department of Health and Senior Services (NJDHSS) collaborated with the Environmental and Occupational Health Sciences Institute (EOHSI) to identify and estimate the impact of major point source air pollution emitters during the study time period 1962 through 1996. Atmospheric dispersion modeling was conducted to estimate the potential exposure of selected air pollution point sources at study subject residences over the study time period. Both ambient gas and particulate estimates were generated from the model. Estimates derived from EOHSI air modeling were then used by NJDHSS to create exposure indices for each study subject.

EOHSI's first step was to identify facilities that were major sources of air pollution in Ocean County. A variety of information sources were used including: the United States Environmental Protection Agency's (EPA) Aerometric Information Retrieval System; EPA's Toxic Release Inventory; the New Jersey Department of Environmental Protection (NJDEP) volatile organic compounds inventory; NJDEP air permitting files; and the Nuclear Regulatory Commission's nuclear power station effluent release information. After reviewing these data sources, EOHSI recommended that two facilities, the Ciba-Geigy facility (formerly the Toms River Chemical plant) and the Oyster Creek Nuclear Generating Station, be assessed for potential impact on study subjects (EOHSI, 1999). The Ciba-Geigy facility was the only facility that met NJDEP's definition of a major emitter of hazardous air pollutants. The Oyster Creek Nuclear Generating Station was recommended due to the unique nature of its releases, its proximity to Dover Township, and community concerns about the facility.

EOHSI's second step was to use computer assisted air dispersion models to assess the relative potential impact of these point source emitters at all study subject residence locations.

Air Dispersion Models

Air dispersion models can simulate the transport and dispersion of point source air emission plumes using information about the source and meteorological data. The Industrial Source Complex model Short-Term version (ISCST) is an EPA approved model for calculating atmospheric dispersion of pollutants over time. The ISCST model requires meteorological data, facility specific data, and the geocoded location of each point source (EOHSI, 2001).

The meteorological information needed for the ISCST model included hourly measurements of temperature, ceiling height, total cloud cover, opaque cloud cover, wind speed, and wind direction. Facility specific information needed for the model included source location, stack height, stack diameter, stack emission exit velocity, emission temperature, and rate of release per hour.

The atmospheric dispersion model used by EOHSI utilized several key assumptions to carry out the model simulations. The ISCST model is based on and assumes that the plume dispersion follows a Gaussian distribution in all three dimensions. The model assumed the terrain to be flat, which is generally true for Dover Township. In addition, the regulatory default options were utilized. The dispersion coefficients were derived from the Pasquill scale for urban areas, while other parameters, such as the Bowen ratio, were also based on urban locations. Plume depletion due to dry deposition was included while wet deposition was not included in the model simulations. The particle size distributions were assumed to be either a particle size of 0.5, 2.5, 10 and 15 micrometers (μm) in aerodynamic diameter with a particle specific gravity of one. The emission rate was assumed to be constant during the modeling runs. The model calculates hourly concentration alues for any spatial location requested. The hourly concentration values were then averaged for each one month period and saved into electronic data files.

Study subjects' residences located within Ocean County were geocoded for latitude and longitude coordinates by NJDHSS and provided to EOHSI for use in the air modeling of the two facilities (see Appendix C for geocoding methods). All NJDHSS and EOHSI staff working on geocoding and modeling were blinded as to case or control status of all residences. EOHSI converted the latitude and longitude coordinates to Universal Transverse Mercator (UTM) coordinates using EPA's conversion program, Concor, as UTM coordinates are required by the model. Residences outside of Ocean County during the study period were considered to have no exposure to emissions from either facility.

Meteorological Data

Three weather stations were identified by EOHSI as potentially appropriate sources of meteorological data for use in the modeling. The stations included the Naval Air Engineering Center in Lakehurst, the Atlantic City weather station, and a weather station located at the Oyster Creek Nuclear Generating Station. All three weather stations are part of the National Weather System (NWS). NWS stations are classified as either first order stations, which operate 24 hours a day, or second order stations, which may not operate 24 hours a day. The meteorological data available for the years of interest from each of the three weather stations have strengths and weaknesses (EOHSI, 2001).

The Naval Air Engineering Center is a second order NWS station located in Lakehurst, approximately seven miles to the west of Dover Township. The Naval Air Engineering Center is the closest weather station to Dover Township and Ciba-Geigy. However, computerized meteorological data for the Naval Air Engineering Center were only available for 1973 onward. Additionally, a reduction in the number of hours of operation of this station in the late 1980s led to decreased data quality and reliability. Consequently, the Navel Air Engineering Center station only has consistently complete hourly data for the years 1973 through 1987.

The Atlantic City weather station, a first order NWS facility, is located approximately 47 miles to the south of Dover Township. Although the Atlantic City station is farther from Dover Township than the other weather stations, its strengths include full time operation, a higher reliability and consistency of the data over time, and a similar relative distance from the Atlantic Ocean as the Ciba-Geigy facility in Dover Township. The Atlantic City station has been operational throughout the entire study time period, 1962 through 1996, with all data available electronically.

The Oyster Creek Nuclear Generating Station has an onsite second order weather station with generally complete and reliable data available from 1982 through 1996. Oyster Creek is located approximately ten miles south of Dover Township. Unfortunately, data prior to 1982 are not available from this station.

Ciba-Geigy Facility

The Ciba-Geigy facility operated from 1952 to 1996. However, very limited emissions data were available to study researchers in order to adequately characterize emissions from the plant over the entire study period. Consequently, information from facility air permits, including stack dimensions and temperatures, were used along with an arbitrary unit emission rate for Ciba-Geigy (since actual emissions were unknown) to estimate a relative air impact at each residential location. The unit emission rate used in the model was 100 grams per second. It was assumed that emissions came from a single stack and the stack parameters were those derived from air permits issued by NJDEP for the stack located in building 108 on the facility property.

The meteorological data from the Atlantic City weather station was selected for use in the modeling of Ciba-Geigy because of its higher quality and completeness through the study time period and the similar distance from the Atlantic Ocean as Dover Township. However, since the Naval Air Engineering Center station is closer to Dover Township, a sensitivity analysis was conducted comparing the relative air impact estimates derived using the Atlantic City station to those derived using the Naval Air Engineering Center station during the period 1973 through 1989. The correlation of these estimates are reported annually and seasonally under Summary of Output Data below.

Relative air exposure values for each study subject's residence were generated by the air model and included: airborne gaseous estimates; airborne particulate matter (PM) estimates for 10 micrometer (µm) diameter particles; and airborne PM estimates for 2.5 µm diameter particles (the fine particulate fraction). EOHSI provided the model estimates to NJDHSS in Access data files.

Since the model used the same arbitrary unit emission rate for each run to generate the relative air exposure estimates for Ciba-Geigy, annual production information, supplied by Ciba-Geigy for the Toms River facility, was used by NJDHSS to take into account the variability of the facility's operations over the study period. The original relative air exposure estimates were adjusted using annual modifying factors (Table F1) based on the yearly production percentage relative to the highest year of production.

Oyster Creek Nuclear Generating Station

The Oyster Creek Nuclear Generating Station began operations in late December 1969. Emission information used for the modeling of Oyster Creek were derived from effluent release records reported by the facility to the Nuclear Regulatory Commission (NRC). Those reports were filed quarterly, beginning in July 1971, and contain data on measured releases of fission gases, iodines, particulate matter, and tritium. The monthly emission input factors used to generate the ambient gas estimates were the NRC reported effluent gas release values for iodine 131. The monthly emission input factors used to generate the ambient particulate estimates were the sum of the NRC reported effluent release values for cesium 137, cobalt 60 and strontium 90 combined. When only quarterly effluent release data were available, those values were divided by three and assigned to each month of the quarter. Monthly computer simulations were not conducted when emission input data were missing in the NRC reports.

Since the Oyster Creek Nuclear Generating Station has had an onsite weather station that operated from 1982 onward, these meteorological data were used for the period 1982 through 1996. For the period from 1971 to 1982, Atlantic City meteorological data were used for the model simulations.

Relative air exposure values for each study subject's residences were generated by the air model and included: airborne gaseous estimates; airborne PM estimates for 15 µm diameter particles; and airborne PM estimates for 0.5 µm diameter particles. EOHSI provided the model estimates to NJDHSS in Access data files.

For months with no simulated estimates due to missing emission input data, residential exposure estimates were imputed. Since no simulations were done prior to July 1971, estimates for the 18 month period, January 1970 through June 1971, were derived by calculating an average value for each residence using the first six months of estimate data (July 1971 through December 1971) for each location. Missing exposure estimate data for two other periods were imputed by calculating an average value for each residence using six months of estimate data, three months before and three months after the missing period.

Summary of Output Data

Exposure Estimate Correlations: Correlation analyses were performed using monthly modeled estimates for all study residences in Ocean County over the study time period and include:

1) Ciba-Geigy airborne relative gas estimates derived using Lakehurst compared to Atlantic City meteorological data (1973-1989);

2) Ciba-Geigy relative airborne gas, airborne PM10, and airborne PM2.5 (1962-1996) estimates derived using Atlantic City meteorological data; and

3) Oyster Creek airborne gas, airborne PM0.5, and airborne PM15 (1972-1996).

Table F2 presents correlation coefficients for the Ciba-Geigy relative airborne gas estimates independently derived using Atlantic City and Lakehurst meteorological data. For each of the years 1973 through 1987, the Ciba-Geigy relative gas estimates were correlated (.66 to .84). In 1988 and 1989, correlations were somewhat lower (.45 and .42) reflecting the diminishing quality of Lakehurst data in the latter time period. During the aggregate period 1973 through 1987, the Atlantic City and Lakehurst derived estimates displayed good correlation by season (.72 to

.76). Because of the high correlation of the estimates, the Atlantic City derived relative estimates were used to develop the Ciba-Geigy point source air exposure indices for the study.

Table F3 presents the Ciba-Geigy correlation coefficients for airborne gas relative to airborne PM10 and airborne PM2.5 by season and all months and years combined. For the years 1962 through 1996, the gas estimates were highly correlated (.95 to .96) with the particulate matter estimates. Consequently, only the Ciba-Geigy relative airborne gas estimates were used to develop the modified Ciba-Geigy point source air exposure indices for the study.

Table F4 presents the Oyster Creek correlation coefficients for airborne gas relative to airborne PM15 and airborne PM0.5 by season and all months and years combined. Overall, the airborne gas estimates were correlated with the airborne particulate estimates (.52 and .52). However, there were seasonal differences in the correlation coefficients with the highest in the spring (.71) and the lowest in the autumn (.16). Although there were seasonal differences in the correlation of airborne gas and particulate matter, the exposure estimates were statistically significantly associated with each other. Because of the overall good correlation between these estimates, only the Oyster Creek airborne gas estimates were used to develop the Oyster Creek point source air exposure indices for the study.

Annual Distribution of Monthly Estimates: Tables F5 through F7 present summaries of the annual distribution of the estimates for Ciba-Geigy gas and modified Ciba-Geigy gas (1962 through 1996) and Oyster Creek gas (1970 through 1996) calculated for all study residences in Ocean County.

The unmodified Ciba-Geigy relative gas estimates (Table F5) displayed a fair amount of annual stability reflecting similarities in meteorology through time. The annual mean values range from 3.03 to 4.22 and the annual maximum values range from 44.4 to 127. The annual median, 10^{th} percentile, and 90^{th} percentile values were all within an order of magnitude each year.

Monthly Ciba-Geigy relative gas estimates were modified by annual production information (Table F1). The Ciba-Geigy modified relative gas estimates

(Table F6) were similar to the unmodified relative gas estimates for the earlier part of the study period, but sharply diverge from the unmodified estimates from 1990 onward reflecting decreased production at the facility.

Oyster Creek gas emission input factors were missing for 27 months during the study time period, 6.4% of all months modeled. Oyster Creek gas estimates for all study residences in Ocean County during these months were imputed as discussed above. The months with missing emission input factors include January 1970 through June 1971, July 1975 through December 1975, and January 1989 through March 1989.

Annually, the Oyster Creek gas estimates (Table F7) displayed the highest values prior to 1980, diminishing to a very small level through the end of the study time period (1996).

Seasonal Distribution of Monthly Estimates: Since the emission input factor used in each monthly simulation for Ciba-Geigy was a unitary value (100 grams per second), seasonal variability was evaluated to assess the impact of meteorology on the relative gas estimates. Although the annual Ciba-Geigy relative gas estimates displayed stability over time, there did appear to be a seasonal influence in the estimates. Figure F1 presents four years of average monthly relative gas estimates for Ciba-Geigy. The years 1965, 1975, 1985 and 1995 were arbitrarily selected and are representative of all study years. In general, it appears that the winter months tended to have the highest mean, median and 90th percentile values.

Location Distribution of Monthly Estimates: Figure F2 presents the monthly Ciba-Geigy relative gas estimates for four residential locations from January 1977 through December 1981. The four locations were selected as a representation of homes in different areas of Dover Township. Substantial variability of the estimates was evident at each of the locations from month to month with a fifteen-fold or more difference between the high and low values for each residence.

Point Source Air Pollution Indices

Point source air pollution indices were developed for the Ciba-Geigy facility and the Oyster Creek Nuclear Generating Station. The air modeling simulations conducted by EOHSI generated monthly ambient gas estimates at each study residence located in Ocean County. The Ciba-Geigy monthly ambient gas estimates were further adjusted using annual modifying factors derived from facility production information. These modified estimates were used to create the Ciba-Geigy index. Indices were calculated as the arithmetic average of the monthly concentration estimates at all residences lived in by the child (or their mother prior to the child's birth) over a specified life time period. Model output data for each residence a child lived were matched to the appropriate month and year. Interview Study residences outside of Ocean County were considered unexposed and a zero monthly value was given during the time the child lived at a non-Ocean County residence.

In the Interview Study, each of the indices were calculated for three time periods: the entire study time period (one year prior to birth to the date of the case's diagnosis); the pregnancy time period (nine months prior to birth); and the postnatal period (the birth month until the month of diagnosis). In the Birth Records Study, each index was calculated for one time period: the pregnancy time period (eight months prior to birth month plus the birth month). Each of the indices were then categorized into three levels (none/low, medium and high) separately based on the distribution of all control data for each Study.

References

EOHSI: Identification of Major Emitters in or near the Area of Dover Township (1961-1996). Environmental and Occupational Health Sciences Institue, Piscataway, New Jersey, 1999.

EOHSI: Atmospheric Dispersion Modeling Analysis to Support the Dover Township Childhood Cancer Epidemiologic Study. Environmental and Occupational Health Sciences Institue, Piscataway, New Jersey, 2001.

Tables

Table F1. Annual Ciba-Geigy Production Summary (in pounds per year)

Note: Outlinded areas are interpolated estimates.

Year	% of Peak	Total	Intermediates	Dyestuffs	Anthraquinone	Bleaches	Chemical Specialties	Pharmaceuticals	Resins/Plastics	Epichlorohydrin	Agrochemicals
1962	56.4%	73,946,721	13,651,531	34,056,762	2,051,420	0	3,950,558	29,450	12,934,732	7,272,268	
1963	60.0%	78,702,572	12,251,352	34,575,743	2,246,000	98,351	4,802,506	0	15,297,071	9,431,549	
1964	62.5%	81,945,800	11,104,880	33,973,212	1,310,200	68,270	4,925,582		19,365,307	11,198,349	
1965	77.2%	101,223,790	13,952,023	39,991,898	2,080,000	152,460	4,464,083		25,746,562	14,836,764	
1966	76.2%	99,916,920	14,424,967	45,028,510	1,910,350	113,680	5,625,106		32,786,707		27,600
1967	66.2%	86,801,616	13,176,523	34,797,053	1,701,500	52,551	4,968,999		30,879,195		1,225,795
1968	83.8%	109,839,296	16,467,324	48,390,518	2,773,198	105,742	5,864,262		34,909,252		1,329,000
1969	88.3%	115,695,624	17,848,302	52,430,519	1,833,700	13,007	5,037,174		36,741,059		1,791,863
1970	82.1%	107,586,544	14,713,580	46,995,347	1,563,200	9,755	4,850,504		38,110,261		1,343,897
1971	87.7%	114,893,979	14,997,244	52,785,105	2,065,900	6,504	4,663,833		39,479,462		895,932
1972	92.8%	121,649,949	16,308,675	56,447,230	3,117,000	3,252	4,477,163		40,848,664		447,966
1973	100.0%	131,071,911	20,105,408	62,136,846	2,321,300	0	4,290,492		42,217,865		0
1974	97.1%	127,315,369	17,502,885	53,431,853	2,173,800	0	6,711,479		47,495,352		0
1975	64.9%	85,125,507	13,072,794	33,351,594	1,214,300		3,306,539		33,185,730		994,550
1976	95.6%	125,312,256	19,523,147	52,719,399	1,623,700		5,612,173		45,000,881		832,956
1977	92.8%	121,606,411	15,663,087	52,674,912	1,256,300	0	4,110,520		47,418,488		483,104
1978	98.0%	128,404,437	16,399,461	55,701,283	2,061,550	0	2,915,284		51,326,859		0
1979	97.7%	128,002,722	18,784,533	50,225,342	2,483,650	0	2,150,180		54,359,017		0
1980	85.5%	112,070,152	14,809,498	43,143,150	1,008,100	0	1,453,833		51,655,571		0
1981	78.2%	102,441,068	14,497,104	34,421,541	1,816,900	0	2,098,666		49,606,857		
1982	78.8%	103,334,451	15,092,247	37,545,012	395,550	0	2,743,500		47,558,143		
1983	73.9%	96,838,709	11,640,498	36,102,675	197,775		3,388,333		45,509,428		
1984	68.9%	90,342,967	8,188,749	34,660,337			4,033,167		43,460,714		
1985	64.1%	84,045,000	4,737,000	33,218,000			4,678,000		41,412,000		
1986	68.0%	89,160,809	4,144,000	38,944,000			4,069,332		42,003,477		
1987	59.5%	77,939,617	2,953,000	28,931,000			3,460,663		42,594,954		
1988	60.3%	79,011,906	4,182,480	28,791,000			2,851,995		43,186,431		
1989	50.4%	66,081,860	3,136,860	14,954,000			3,661,000		44,330,000		
1990	33.8%	44,315,907	2,091,240	17,619,000			2,440,667		22,165,000		
1991	14.9%	19,552,953	1,045,620	17,287,000			1,220,333				
1992	16.8%	22,052,000		22,052,000							
1993	16.6%	21,762,000		21,762,000							
1994	15.5%	20,336,000		20,336,000							
1995	10.1%	13,288,000		13,288,000							
1996	11.1%	14,494,000		14,494,000							

Table F2. Correlation of Monthly Ciba-Geigy Relative Gas Estimates Derived from Meteorologic Data from the Atlantic City and Lakehurst Stations, by Year from 1973 through 1989

Year	Correlation			
1973	.78			
1974	.84			
1975	.81			
1976	.78			
1977	.66			
1978	.70			
1979	.77			
1980	.73			
1981	.77			
1982	.77			
1983	.79			
1984	.74			
1985	.76			
1986	.74			
1987	.75			
1988	.45			
1989	.42			
Year	**Spring**	**Summer**	**Autumn**	**Winter**
1973-1987	.72	.72	.76	.76

Table F3. Ciba-Geigy Estimate Correlations Relative to Gas, 1962-1996

	Overall	Winter	Spring	Summer	Autumn
PM10	.95	.96	.95	.95	.95
PM2.5	.95	.96	.95	.95	.95

Note: All correlations are statistically significant at $p < 0.001$

Table F4. Oyster Creek Exposure Correlations Relative to Gas, 1972-1996

	Overall	Winter	Spring	Summer	Autumn
PM0.5	.52	.55	.71	.55	.16
PM15	.52	.48	.71	.56	.17

Note: All correlations are statistically significant at $p < 0.001$

Table F5. Distribution of Monthly Ciba-Geigy Gas Unmodified Relative Impact Units by Year, All Ocean County Study Locations, 1962-96

Year	Mean	Median	10th Percentile	90th Percentile	Maximum
1962	3.47	1.85	0.40	7.34	70.5
1963	3.70	2.04	0.44	8.05	79.2
1964	3.45	1.78	0.60	8.01	88.5
1965	3.09	1.53	0.49	7.31	66.1
1966	3.35	1.75	0.40	7.95	67.9
1967	3.65	1.76	0.42	9.02	68.3
1968	3.27	2.05	0.83	6.59	59.1
1969	3.06	1.72	0.46	7.07	62.8
1970	3.36	1.92	0.67	7.53	65.7
1971	3.26	1.65	0.32	8.25	48.3
1972	3.03	1.39	0.46	7.12	61.7
1973	3.28	2.04	0.52	7.20	48.7
1974	3.40	2.03	0.57	7.83	50.1
1975	3.66	2.21	0.62	8.52	61.6
1976	3.51	1.89	0.43	7.90	68.4
1977	3.32	1.74	0.59	7.05	66.4
1978	3.66	1.58	0.33	8.91	110
1979	3.29	1.43	0.42	7.57	87.4
1980	4.22	2.06	0.59	9.95	127
1981	3.72	2.11	0.72	8.74	84.3
1982	3.41	1.70	0.64	7.66	62.0
1983	3.56	1.79	0.61	8.11	76.5
1984	3.60	1.88	0.58	8.38	62.1
1985	3.21	1.71	0.53	7.54	52.6
1986	3.61	1.92	0.67	8.53	53.0
1987	3.48	1.45	0.50	8.89	65.8
1988	3.73	2.02	0.54	8.75	85.1
1989	3.28	1.71	0.58	7.82	66.0
1990	3.30	1.65	0.55	7.43	85.2
1991	3.50	1.95	0.65	7.77	75.5
1992	3.44	1.85	0.52	8.15	59.4
1993	3.75	1.83	0.64	8.48	85.1
1994	3.55	1.82	0.52	8.24	103
1995	3.42	1.93	0.50	7.75	74.9
1996	3.19	1.90	0.61	7.07	44.4

Table F6. Distribution of Monthly Ciba-Geigy Gas Modified Relative Impact Units by Year, All Ocean County Study Locations, 1962-1996

Year	Mean	Median	10th Percentile	90th Percentile	Maximum
1962	1.96	1.04	0.23	4.14	39.8
1963	2.22	1.22	0.27	4.83	47.6
1964	2.16	1.12	0.37	5.01	55.4
1965	2.39	1.18	0.38	5.65	51.1
1966	2.55	1.33	0.31	6.06	51.8
1967	2.41	1.17	0.28	5.97	45.2
1968	2.74	1.72	0.69	5.52	49.5
1969	2.70	1.52	0.41	6.24	55.4
1970	2.76	1.57	0.55	6.18	53.9
1971	2.86	1.44	0.28	7.23	42.4
1972	2.81	1.29	0.43	6.60	57.3
1973	3.28	2.04	0.52	7.20	48.7
1974	3.30	1.97	0.56	7.61	48.6
1975	2.37	1.44	0.40	5.54	40.0
1976	3.35	1.81	0.41	7.56	65.4
1977	3.08	1.61	0.54	6.54	61.6
1978	3.59	1.55	0.33	8.73	108
1979	3.21	1.40	0.41	7.40	85.4
1980	3.61	1.76	0.50	8.51	109
1981	2.91	1.65	0.56	6.83	65.9
1982	2.69	1.34	0.50	6.04	48.9
1983	2.63	1.32	0.45	5.99	56.5
1984	2.47	1.30	0.40	5.78	42.8
1985	2.06	1.10	0.34	4.84	33.7
1986	2.46	1.30	0.46	5.80	36.1
1987	2.07	0.86	0.30	5.29	39.1
1988	2.25	1.22	0.33	5.27	51.3
1989	1.65	0.86	0.29	3.94	33.3
1990	1.12	0.56	0.19	2.51	28.8
1991	0.52	0.29	0.10	1.16	11.3
1992	0.58	0.31	0.09	1.37	9.99
1993	0.62	0.30	0.11	1.41	14.1
1994	0.55	0.28	0.08	1.28	16.0
1995	0.35	0.20	0.05	0.79	7.60
1996	0.35	0.21	0.07	0.78	4.91

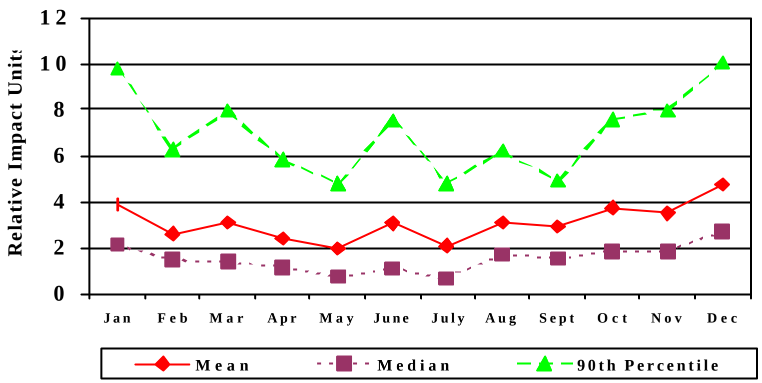
Table F7. Distribution of Monthly Oyster Creek Gas Ambient Air Estimates (fCi/m^3) by Year, All Ocean County Study Locations, 1970-1996

Year	Mean	Median	10th Percentile	90th Percentile	Maximum
1970	0.36	0.35	0.23	0.50	3.7
1971	0.36	0.35	0.19	0.51	4.5
1972	0.73	0.64	0.23	1.3	16
1973	0.82	0.72	0.14	1.61	17
1974	0.38	0.26	0.080	0.86	11
1975	0.92	0.76	0.40	1.6	21
1976	0.95	0.59	0.18	2.4	26
1977	0.73	0.31	0.034	1.9	19
1978	0.97	0.49	0.11	2.4	25
1979	0.78	0.61	0.30	1.4	20
1980	0.008	<0.004	<0.004	0.034	0.96
1981	0.080	0.065	0.030	0.14	2.2
1982	0.088	0.030	<0.004	0.29	3.8
1983	<0.004	<0.004	<0.004	<0.004	0.072
1984	0.034	<0.004	<0.004	0.14	2.6
1985	0.38	0.35	0.11	0.65	7.5
1986	0.061	0.004	<0.004	0.19	3.4
1987	0.011	0.004	<0.004	0.034	0.35
1988	0.008	0.008	<0.004	0.023	0.26
1989	0.042	0.008	<0.004	0.22	0.45
1990	0.004	0.004	<0.004	0.004	0.053
1991	0.004	<0.004	<0.004	0.008	0.076
1992	0.004	0.004	<0.004	0.008	0.15
1993	<0.004	<0.004	<0.004	<0.004	0.053
1994	<0.004	<0.004	<0.004	0.004	0.034
1995	<0.004	<0.004	<0.004	<0.004	0.015
1996	<0.004	<0.004	<0.004	<0.004	<0.004

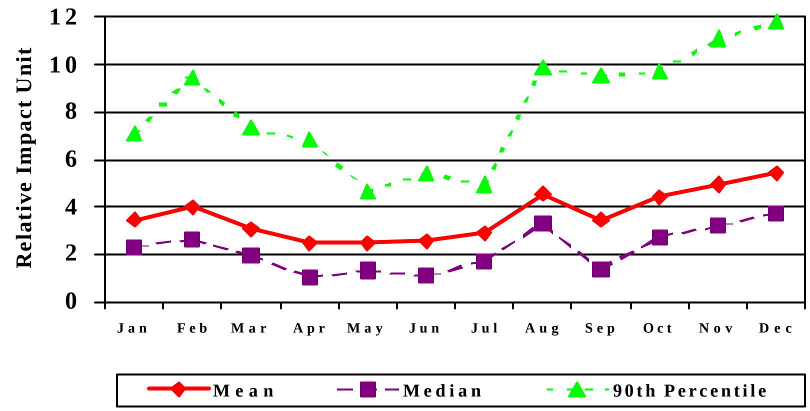
Figures

Figure F1. Average Monthly Ciba-Geigy Unmodified Relative Impact Units at All Ocean County Locations Combined for Selected Years

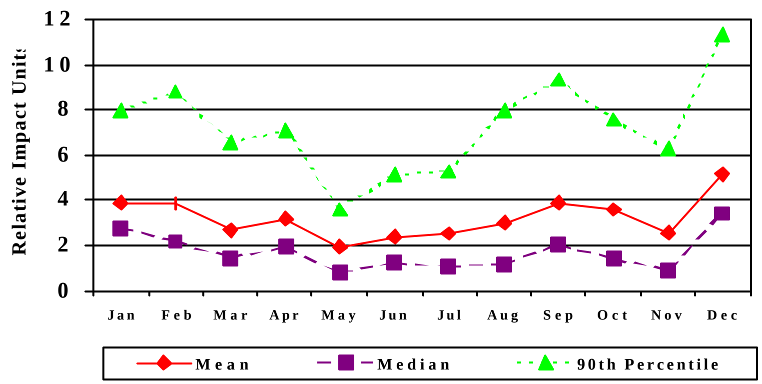
1965



1975



1985



1995

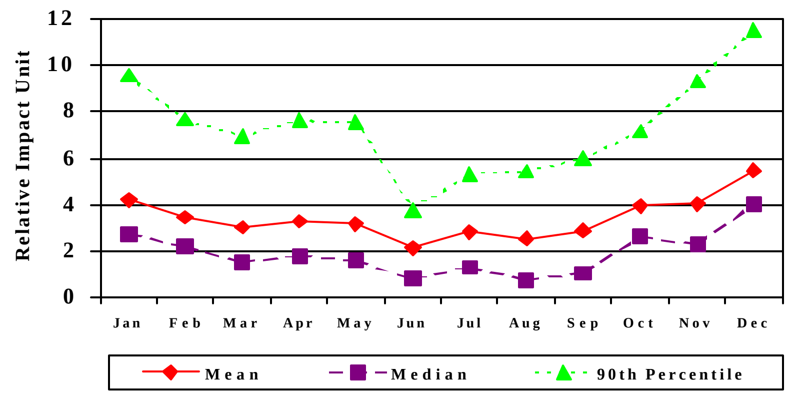
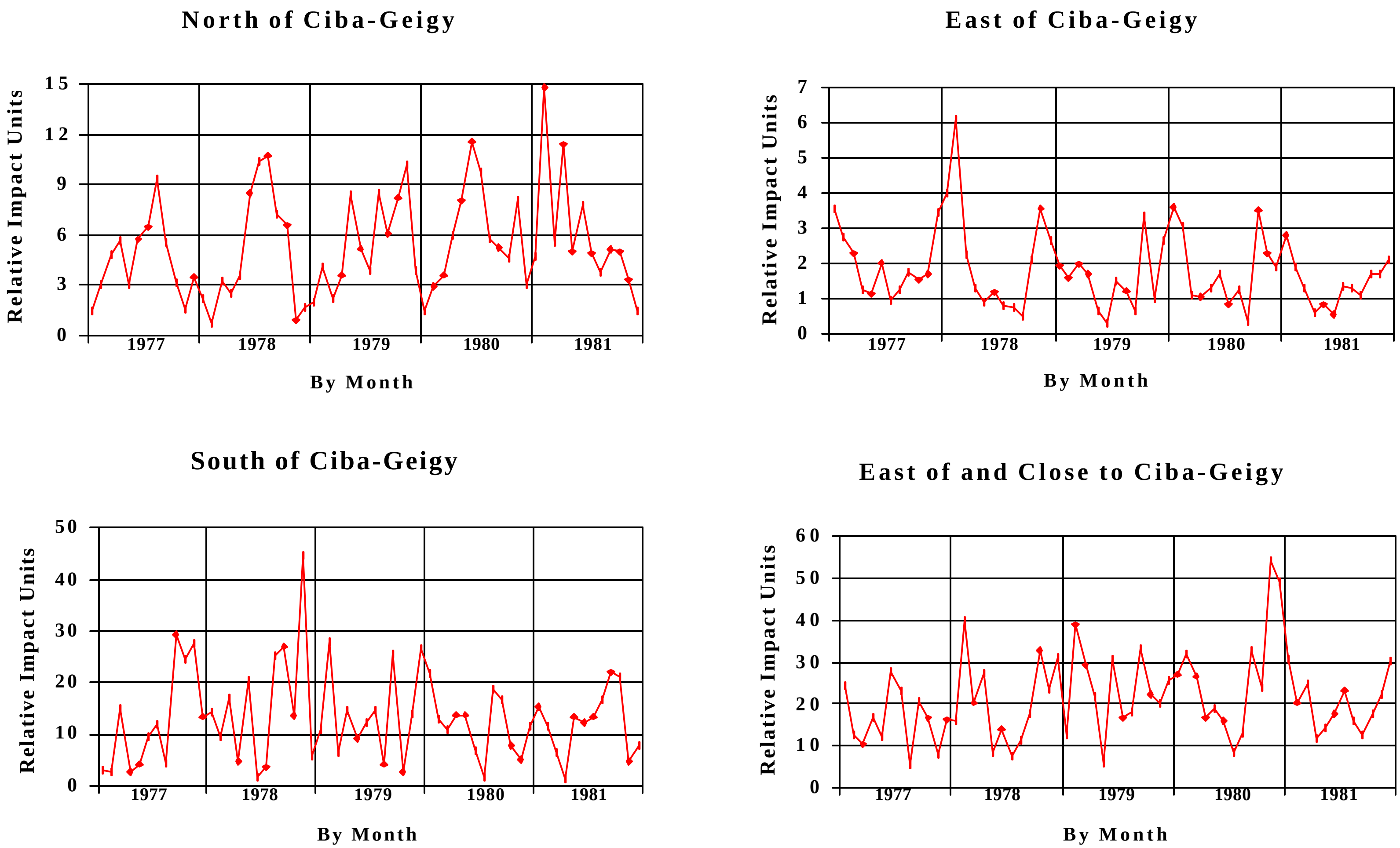


Figure F2. Ciba-Geigy Unmodified Relative Impact Units at Four Residential Locations (January 1977 Through December 1981)



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endix G: Proximity to Sites of Concern Assessment

Introduction

In order to account for the potential exposure to residents living near sites of concern in Dover Township, an assessment of residential proximity to selected sites was conducted. Exposure pathways that are potentially correlated with proximity to a site of concern include: direct contact (trespassing on the site); air exposure to particulates and gases from the site; the settling of particulates in residential yards; the accumulation of soil gases in basements; and the contamination of groundwater used for drinking water. Groundwater contamination pathways are addressed in Appendix D. Air exposure pathways are addressed in Appendix F.

Sites were selected based primarily on information from the New Jersey Department of Environmental Protection's (NJDEP) Known Contaminated Sites List. The Known Contaminated Sites List contains the following information: the location of the site; the NJDEP bureau that is assigned to the site; on-site media that have been contaminated above cleanup criteria/standards; off-site media that have been contaminated above cleanup criteria/standards; the proposed site remedy; and remedial activities that have taken place. This list was reviewed to identify those sites that were unusual and that could have had completed exposure pathways in the past. The criteria for selecting sites of concern for assessment included: the presence of off-site contamination; the potential for trespassing on the site; types of contaminants that have been detected; the complexity of the site, including National Priority List status; uncommon aspects of the site; and public health concerns that have been raised by the community. NJDEP and the Ocean County Health Department were consulted to supplement the information provided in the Known Contaminated Sites List and to assist in the review.

Selected Sites of Concern

Seven sites were selected for an assessment of residential proximity during the study period (see Figure G1):

- the Ciba-Geigy facility (NJDHSS and ATSDR, 2001a);
- the Ciba-Geigy pipeline that carried treated wastewater from the facility for disposal in the ocean (NJDHSS and ATSDR, 2001a);
- a section of the Toms River which received treated wastewater discharges from the Ciba-Geigy facility during the years 1952 through 1966 (NJDHSS and ATSDR, 2001a);
- the Reich Farm Superfund site (NJDHSS and ATSDR, 2001b);
- the Dover Township Municipal Landfill (NJDHSS and ATSDR, 2001c);
- the Ocean County Landfill; and
- the Toms River Coal Gas Site.

Proximity to Sites of Concern Indices

Selected sites were geocoded and placed on a map along with geocoded study subject residences. The distance of each residence to the border of each site was determined using ArcView GIS. Residences within one-half mile of each site border were identified. For the Interview Study, proximity to sites of concern indices were developed based on the proportion of study time that a child resided within one-half mile from that site. Since only the birth address was available for each study subject in the Birth Records Study, proximity to sites of concern indices were based on whether the birth address was within one-half mile of each site.

Because the Ciba-Geigy pipeline was documented (NJDHSS and ATSDR, 2001b) to have ruptured and waste waters released on several occasions, a second index for the pipeline was developed. The new pipeline index was a refinement of the cruder index of distance from the entire pipeline since it restricted the exposure pathway to a specified distance from each of the pipeline breaks. The new pipeline index only includes residences within one-half mile of a pipeline break during or after the year the break occurred. The three pipeline breaks were documented as occurring in 1984, 1988, and 1989.

Proximity to sites of concern indices in the Interview Study were developed for each child during three time periods: the entire time period for the child (one year prior to birth until the case's diagnosis date); the pregnancy period of nine months prior to birth; and the post birth period defined as date of birth to the case's diagnosis date.

References

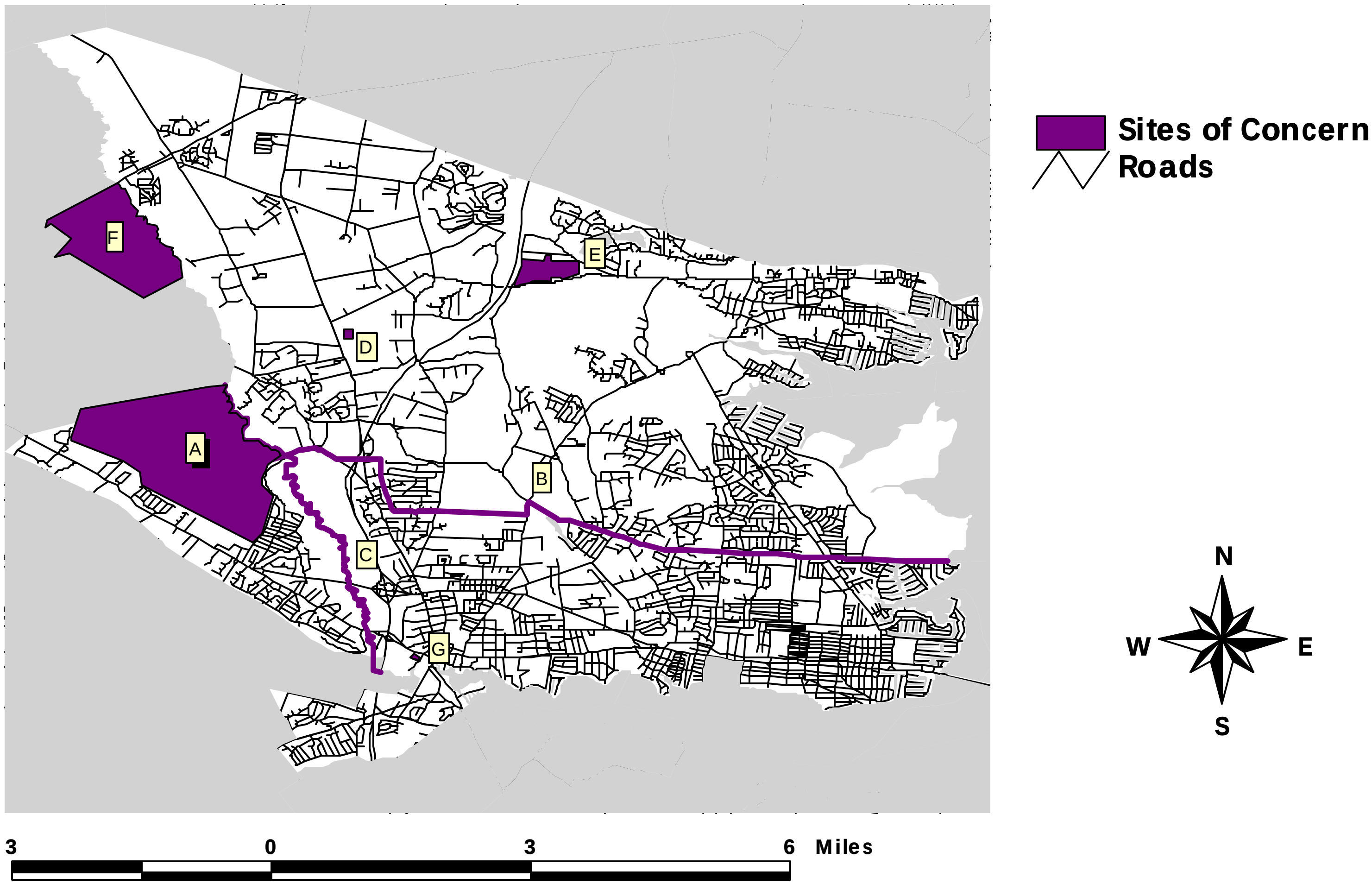
NJDHSS and ATSDR: Ciba-Geigy Corporation Site Public Health Assessment, Trenton, New Jersey, 2001a.

NJDHSS and ATSDR: Reich Farm Public Health Assessment, Trenton, New Jersey, 2001b.

NJDHSS and ATSDR: Dover Township Municipal Landfill Public Health Assessment, Trenton, New Jersey, 2001c.

Figures

Figure G1. Location of Sites of Concern



Appendix H: Parental Occupation Assessment

Introduction

The association of parental occupation with childhood cancer in Dover Township was assessed through the analysis of self-reported information collected by structured interview. Trained interviewers collected both maternal and paternal job histories for the period one year prior to birth to the date of diagnosis. Information was collected for every parental job, whether full or part-time employment, that lasted three months or longer. This included work that was inside or outside the home, for pay or non-pay, and all civilian or military jobs. Information was collected for all parents, including birth parents, adoptive parents, step-parents, and guardians. Jobs held by adoptive parents prior to the child's adoption were not collected.

Self-reported job information included: the name and address of the company; a description of the company's activities and products; the job title and description of the functions and activities of the job; the dates of employment; and full or part-time status. In addition, parents were asked whether each job involved any exposure to pre-specified groups of chemicals and job activities. The number of hours per week of exposure was collected for each job. The list of chemical/substance categories included: solvents, dry cleaning agents and degreasers; paints and thinners; dyes and pigments; petroleum products; pesticides; plastics and resins; metals; and ionizing and low frequency radiation. The list of job/activity categories included: painting, printing, dye coloring and graphics; electrical and electronics; metal work; motor vehicle work; chemical manufacturing; agriculture, yard maintenance and pest control; cleaning and maintenance outside the home; medical professions; and jobs requiring radiation badge. The list of chemical/substance categories and job/activity categories were provided to parents prior to the interview.

Occupational Coding

From the self-reported parental job histories, descriptive and analytic statistics were calculated. For descriptive purposes, each job was classified using the North American Industry Classification System (NAICS) and the Standard Occupational Classification (SOC) coding schemes (U.S. Department of Commerce, 1998; U.S. Department of Commerce, 1980). Additionally, an industrial hygienist's (IH) hazard rating of exposure was conducted and analyzed for each of the chemical/substance and job/activity categories. All occupational coding and hazard ratings were conducted by individuals blinded to the case or control status of each study subject.

Two coders, one an industrial hygienist and the other a trained occupational coder, worked independently to assign each job a NAICS and SOC code to the third digit. Comparisons were performed between the NAICS and SOC codes given by each coder and discrepancies were resolved based on the consensus reached between the two coders. Any outstanding discrepancies that could not be resolved by consensus were evaluated by a Certified Industrial Hygienist (CIH) for a final determination.

An industrial hygienist (IH) provided a professional assessment of occupational exposures for each reported job based on the chemical/substance and job/activity categories. These assessments utilized all information provided by the informant, including the industry, job title and activities, the self-reported assessments of exposure, and the duration of exposure.

The assessment of the chemical/substance categories was based on professional judgements as to the intensity of the exposure and the duration of exposure. The IH ratings for the chemical/substance categories consisted of three levels: no or negligible hazard; low hazard; and high hazard. Exposure was broadly defined as referring to any contact between occupational materials or agents and the employee. The IH ratings for the chemical/substance categories were weighted towards the intensity of exposure relative to the duration of exposure. Schematically, the IH ratings for the chemical/substance categories were based on Table H1.

An IH rating was also conducted for the job/activity categories. The industrial hygienist based these assessments on industrial hygiene knowledge as to the likelihood that a particular job/activity was conducted as part of a reported job. Each job/activity category was rated as ever or never.

A ten percent random sample of parent's job histories was selected for review by a CIH. The CIH was responsible for reviewing the NAICS codes, SOC codes, and the IH ratings. Based on this sample of job histories, the CIH evaluated the accuracy of the NAICS and SOC coding and IH Ratings.

Occupational Indices

Descriptive statistics were developed for each NAICS and SOC grouping. Exposure indices were developed for each IH rating group based on three different exposure time periods: the entire study time period for the child; the pre birth period defined as one year prior to birth, to birth; and the post birth period defined as date of birth to the diagnosis date. Maternal and paternal occupational IH ratings were analyzed separately. For the pre-birth analysis, only biological parents' information was evaluated. Occupational histories for adoptive parents, step-parents, and custodial parents were included only for those periods when the parent was part of the child's family.

The NAICS and SOC codes were collapsed to two digit groupings because of sparseness of the data. Parents were included in a grouping based on whether they ever worked in a particular industry (NAICS) or job (SOC) two digit category. NAICS and SOC category frequencies are presented for the entire study time period.

The chemical/substance and job/activity IH ratings were based on whether the parent was ever exposed to a particular category during any of the three time periods evaluated. Although each job was initially given a chemical/substance category IH rating of none/negligible, low, or high exposure, because of the sparseness of the data these categories were collapsed to ever/never.

References

U.S. Department of Commerce: North American Industry Classification System, United States, 1997. U.S. Department of Commerce's National Technical Information Service, Washington, DC, 1998.

U.S. Department of Commerce: Standard Occupational Classification Manual 1980. U.S. Government Printing Office, Washington, DC, 1980.

Tables

Table H1. IH Ratings for the Chemical/Substance Categories

Duration	Intensity		
	None/Negligible	**Low**	**High**
None/Negligible *	No Hazard	No Hazard	Low Hazard
Low	No Hazard	Low Hazard	High Hazard
High	No Hazard	Low Hazard	High Hazard

* Negligible duration was considered jobs of less than three hours of exposure per week.

Appendix I: Assessment of Environmental Exposures in Case-Control Epidemiologic Studies

In environmental epidemiology, researchers examine the relationship between exposures to factors in the environment and subsequent development of disease. One of the most difficult challenges of an environmental epidemiologic study is the accurate assessment of the study subjects' environmental exposures. In fact, exposure assessment is generally considered the major methodological problem in environmental epidemiology (Rothman, 1993).

Environmental exposure has been defined as "the concentration of an agent at the boundary between an individual and the environment as well as the duration of contact between the two" (Hatch and Thomas, 1993), and as "the opportunity for transfer of an environmental agent to the body" (Links et al., 1995). This "transfer" (for example, through absorption of the agent through the lungs, skin or gastrointestinal tract and distribution of the agent through the body) may result in a dose of the environmental agent over a critical period of time to the organ or system in the body that is sensitive to the effects of the agent. Epidemiologists ideally would like to accurately measure environmental exposure or dose during the critical period of time that the disease process is initiated or promoted for each case and control study subject.

In a retrospective case-control study (by definition, the study of individuals with and without the disease of interest that is conducted after the development of disease), researchers need to estimate levels of environmental exposure in the past, sometimes many years prior to the time the study is being conducted. Unfortunately, the necessary environmental exposure measurements rarely exist for study subjects for these historic time periods of interest. Even if general or area-wide environmental measurements exist, there is a need to determine exposure levels specific to the environment of the individual study subjects.

Prior case-control environmental epidemiologic studies have used a variety of methods for environmental exposure assessment. In rare circumstances, historic personal exposure or dose measurements have been available. Some studies have used current personal exposure or dose measurements as a surrogate for past exposures at the relevant time for disease process initiation. Crude measures of exposure potential (such as historic residential proximity to a site of concern or air pollutant emission source, or residential location within a geographic area served by a water system) have been the most common method of historic exposure assessment in environmental epidemiology. In recent years, however, there is growing use of computer modeling to reconstruct an approximation of historic exposure conditions. Examples of these approaches will be discussed below.

Personal Exposure or Dose Measurements: Although historic measures of individual exposure or dose are closest to the ideal, only a limited number of prospective or nested case-control studies have been able to utilize stored biological samples or previously collected individual measurements. Stored blood sera have been used in case-control epidemiological studies of organochlorine chemicals and breast cancer (Krieger et al., 1994; Helzlsouer et al., 1999; Dorgan et al., 1999) and non-Hodgkin's lymphoma (Rothman et al., 1997). For example, a nested case-control study of women who had donated blood in 1974 or 1989 found that women who had developed breast cancer up to 20 years later did not have higher levels of 1,1-dichloro-2,2-*bis*(*p*-chlorophenyl)ethylene (DDE) or polychlorinated biphenyls (PCBs) in their stored sera, compared to women who had not developed breast cancer (Helzlsouer et al., 1999).

In the absence of historic measurements of individual exposure, some studies have used current measurements of exposure or dose for each case and control study subject. Using current measurements, however, can be problematic, as the present environment may differ from that which existed historically. Current personal exposure or dose measurements have been used, however, in case-control environmental epidemiologic studies of residential electromagnetic fields and childhood cancer (Savitz et al., 1988; UK Childhood Cancer Study Investigators, 1999; Linet et al., 1997; Preston-Martin et al., 1996; McBride et al., 1999), polychlorinated biphenyl (PCB) exposure and breast cancer (Wolff et al., 1993; Aronson et al., 2000), disinfection byproducts in drinking water and neural tube birth defects (Klotz and Pyrch, 1999), and arsenic in toenail clippings and household drinking water and cancer (Karagas et al., 1998). In each study, the measurements were individually made for each case and control study subject after the disease of interest had been diagnosed in cases. For example, Savitz and colleagues (1988) conducted a study of childhood cancer and residential exposure to magnetic fields and found that measurements of magnetic fields made in the homes of case and control children under low power conditions showed a modest association with cancer risk.

Proximity Exposure Assessments: Proximity measurements are another method of estimating individual exposures that frequently have been used in case-control studies. Proximity measurements usually measure the distance from each study subject's residence to selected suspect sources, for example: an industrial facility, or a major highway. Alternatively measurements may be made using specified zones of exposure (for example: a one mile concentric circle drawn around a nuclear power plant; a specified area encompassing that portion of a community where odor complaints were reported; or a defined area served by a contaminated public water supply well).

Proximity measurements have been used in numerous and diverse case-control epidemiological studies including: selected cancers and residential proximity to cranberry bogs (Aschengrau et al., 1996); childhood leukemia and residential proximity to main roads and petrol stations (Harrison et al., 1999); childhood cancer and residential proximity to high voltage facilities (Olsen et al., 1993); and congenital central nervous system malformations and residential distance to a polyvinyl chloride (PVC) polymerization plant (Edmonds et al., 1978). In the study of various cancers and residential proximity to cranberry cultivation in Cape Cod for example, living within a half mile of a cranberry bog was found to be associated with brain cancer, but not with seven other cancers investigated (Aschengrau et al., 1996).

Computer Models to Reconstruct Historic Exposures: Computer-assisted mathematical modeling of environmental exposures has been used in prior case-control epidemiological studies when direct measurement of the environmental exposures of interest were not available or possible to obtain. Modeling can be used to create reconstructions of past environmental conditions (with input based on available historic records and using mathematical processes to predict environmental quality parameters of interest). Modeling to develop estimates of individual environmental exposures, though uncommon, is being used in a growing number of case-control epidemiological studies, including: a study of lung cancer and arsenic in drinking water (Ferreccio et al., 2000); a study of stillbirth and atmospheric dispersion of arsenic (Ihrig et al., 1998); a study of breast cancer and residence near industrial facilities or traffic in Long Island, NY (Lewis-Michel et al., 1996); a study of childhood cancer and exposure to motor vehicle exhaust (Feychting et al., 1998); and a study of childhood cancers and distance-weighted traffic density (Pearson et al., 2000). In the study of lung cancer and arsenic concentrations in drinking water in Chile, individual arsenic in drinking water values were created through models using lifetime residential histories and historical water company records of arsenic concentrations in drinking water by year. The study found that there was synergy between cigarette smoking and arsenic in drinking water and the subsequent development of lung cancer. (Ferreccio et al., 2000).

While epidemiological researchers would prefer to use actual individual environmental measurements or biological samples that were gathered during the period of disease initiation or promotion, the desired data are rarely available. For this reason, the epidemiologist must develop approximations of individual exposures based on the best information available. The choice of the specific methods to employ for environmental exposure assessment depends on the nature of the study hypotheses, the study population and time frame, the quality and completeness of historic environmental data, the existence of technology to reconstruct exposure, and the availability of resources.

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