Health Consultation

Public Comment Release

Historical Outdoor Air Emissions in the Endicott Area

INTERNATIONAL BUSINESS MACHINES CORPORATION (IBM)

VILLAGE OF ENDICOTT, BROOME COUNTY, NEW YORK

EPA FACILITY ID: NYD002233039

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U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Agency for Toxic Substances and Disease Registry
Division of Health Assessment and Consultation
Atlanta, Georgia 30333

Health Consultation: A Note of Explanation

An ATSDR health consultation is a verbal or written response from ATSDR to a specific request for information about health risks related to a specific site, a chemical release, or the presence of hazardous material. In order to prevent or mitigate exposures, a consultation may lead to specific actions, such as restricting use of or replacing water supplies; intensifying environmental sampling; restricting site access; or removing the contaminated material.

In addition, consultations may recommend additional public health actions, such as conducting health surveillance activities to evaluate exposure or trends in adverse health outcomes; conducting biological indicators of exposure studies to assess exposure; and providing health education for health care providers and community members. This concludes the health consultation process for this site, unless additional information is obtained by ATSDR which, in the Agency's opinion, indicates a need to revise or append the conclusions previously issued.

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Prepared By:

U.S. Department of Health and Human Services
Agency for Toxic Substances and Disease Registry
Division of Health Assessment and Consultation

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List of Abbreviations

AQS   Air Quality System

ATSDR   Agency for Toxic Substances and Disease Registry

BCHD   Broome County Health Department

Freon 113   1,1,2-trichloro-1,2,2-trifluoroethane

IBM   International Business Machines Corporation

MC   methylene chloride (also known as dichloromethane)

NYSDEC   New York State Department of Environmental Conservation

NYSDOH   New York State Department of Health

PCE   tetrachloroethylene (also known as perchloroethylene)

TCA   1,1,1-trichloroethane (also known as methyl chloroform)

TCE   trichloroethylene

TRI   Toxics Release Inventory

VOCs   volatile organic compounds

WBESC   Western Broome Environmental Stakeholders Coalition

Summary

In this health consultation, the Agency for Toxic Substances and Disease Registry (ATSDR) describes its evaluation of past environmental exposures to air pollution in and around Endicott Village, located in the Town of Union in Broome County, New York. Consistent with community concerns, the evaluation focuses on air quality impacts associated with emissions of volatile organic compounds (VOCs) from the former International Business Machines Corporation (IBM) facility located near the center of the village. The evaluation focuses on the time frame (i.e., years before 1994) when VOC emissions from industrial sources throughout the area were considerably higher than their current levels. Although this document focuses largely on IBM, ATSDR considered air quality impacts from other local industrial operations and emissions sources, to the extent appropriate.

This health consultation's conclusions are based on available air emissions data, dispersion modeling studies, permitting records, and numerous other publications. During the 2 years preceding this report, ATSDR obtained documents and relevant insights from IBM, the New York State Attorney General, the New York State Department of Environmental Conservation (NYSDEC), the New York State Department of Health (NYSDOH), the Western Broome Environmental Stakeholders Coalition (WBESC), and several community members. ATSDR considered all information provided by these parties when preparing this health consultation.

The following paragraphs review ATSDR's key findings on several individual topics:

- **Why is ATSDR evaluating historic air emissions for this site?** ATSDR prepared this health consultation to respond to specific health concerns that residents communicated to the agency and to determine whether residents were previously exposed to outdoor air pollution at levels that present a public health hazard.

- **What exposure scenarios did ATSDR consider?** This health consultation addresses *environmental* exposures to air pollutants that IBM and other facilities previously released. It does not address *occupational* exposures, which generally do not fall under ATSDR's mandate. However, the National Institute for Occupational Safety and Health, part of the Centers for Disease Control and Prevention (CDC), is assessing the feasibility of a study to evaluate associations between health effects and past worker exposures at IBM (NYSDOH, ATSDR, Broome County Health Department [BCHD], 2006). Furthermore, this health consultation focuses on residents' *direct* inhalation exposures to air pollutants released from the IBM facility. *Indirect* exposures, or the possibility that air pollutants might have deposited on the ground and then become available for uptake in the food chain (e.g., via fruits and vegetables), were not assessed because the VOCs considered in this analysis are not taken up into fruit or garden vegetables in significant amounts.

- **Why did ATSDR use models to evaluate air pollution levels in Endicott for 1987–1993?** Outdoor air pollution was not measured in Endicott before 1994, and measurements cannot be made now to characterize past air pollution levels. Consequently, ATSDR used a computer model to estimate how air emissions from the former IBM facility affected local air quality. The model estimates a facility's air quality impacts on the basis of the amounts of chemicals released into the air, local weather conditions, and a scientific understanding of

how pollutants move through the air. Modeling could not be conducted for years before 1987 because of the lack of chemical-specific emissions data.

- **What chemicals were considered in ATSDR's modeling?** Of the hundreds of chemicals that the former IBM facility used in its production processes, sufficient information was available to support a reliable modeling analysis for only 14 VOCs (Table 1, page 37). The other chemicals that were excluded from the modeling either have relatively low toxicities or were not used in quantities large enough to trigger emissions reporting in the late 1980s under federal community right-to-know regulations (i.e., the U.S. Environmental Protection Agency's [EPA's] Toxics Release Inventory). In other words, ATSDR's modeling generally focused on toxic chemicals that the former IBM facility used and released in greatest quantities in the late 1980s and early 1990s. These chemicals were primarily VOCs that had been used as solvents.

- **Did sources other than IBM release these same chemicals into the air?** Most of the 14 chemicals considered in ATSDR's modeling were used by industrial and commercial facilities in the Endicott area. However, for several of these chemicals, the available emissions data show that releases from the former IBM facility accounted for an extremely large portion of the total air emissions that occurred from all nearby facilities. Thus, for these chemicals, the focus of the modeling on IBM's emissions is appropriate. Although the modeling results do not account for releases from other industrial and commercial facilities, contributions from these other sources are acknowledged and characterized, as appropriate, in this health consultation. Some of the chemicals considered in this health consultation are also found in common consumer and household products used in indoor settings; the modeling analysis does not account for potential releases from such items.

- **How did IBM's air emissions affect local air quality before 1994?** The extent to which the IBM facility affected air quality varied with location and time. The areas with the highest air quality impacts generally were closest to the center of previous production operations (i.e., nearest where McKinley Avenue passes through the former facility), and impacts attributed to the IBM facility decreased considerably with downwind distance. In addition, air quality impacts attributed to IBM decreased substantially in the late 1980s, as the facility began to phase out many of its toxic chemical uses. Detailed estimates of air quality impacts and how they changed with location and time are described in this health consultation.

- **How reliable are ATSDR's modeling results?** Air pollution levels that are estimated by models have inherent uncertainties and limitations. However, ATSDR intentionally focused on time frames and chemicals for which sufficient information was available to support a defensible modeling study. The modeling results presented in this health consultation are ATSDR's best estimates of past air quality impacts resulting from IBM's air emissions during 1987–1993. Although these estimates are based on scientifically rigorous modeling approaches and reasonable model inputs, the results may still understate or overstate actual air quality impacts that occurred. Air quality impacts could not be evaluated for all relevant chemicals for years before 1987 because of the lack of information on chemical emissions from local industrial facilities.

- **Did the estimated past air pollution levels pose a health hazard?** ATSDR determined, using conservative health comparison values, that three contaminants of concern (formaldehyde, methylene chloride [MC], and tetrachloroethylene [PCE]) needed further evaluation. In addition, trichloroethylene (TCE) also was considered a contaminant of concern because of its presence in other environmental media (e.g., indoor air) and because of community concerns and information gathered during ATSDR's evaluation process.

  ATSDR evaluated the possible health effects of past air exposures to the four contaminants of concern and other VOCs emitted from the former IBM plant to residents near the facility during 1987–1993. On the basis of this evaluation, ATSDR determined that these past exposures present no apparent public health hazard. This means that adverse non-cancer health effects are not expected, and the likelihood of cancer resulting from an exposure during 1987–1993 is very low to low (ranging from greater than one theoretical excess cancer case for every million persons exposed to less than one theoretical excess cancer case for every 10,000 persons exposed).

  ATSDR also evaluated, using its guidance on chemical mixtures, the possible health effects of past air exposures to the combination of VOCs emitted from IBM during 1987–1993. On the basis of this evaluation, adverse non-cancer health effects are not expected, and the cancer risk from the combined past air exposures to VOCs is considered to be low.

  Although MC and PCE exposures could be qualitatively evaluated for a longer period (1977–1993), these results were uncertain because ATSDR could not quantify exposure levels from computer modeling for years before 1987. Moreover, ATSDR cannot be certain about exposure levels to TCE that may have been greater than the exposures to formaldehyde, MC, and PCE for certain time frames. Because of insufficient information, the public health implications of air exposures from the IBM plant before 1987 could not be determined; ATSDR has categorized exposures for this earlier time frame as an indeterminate public health hazard.

  Although ATSDR determined that adverse health effects were unlikely for persons who were exposed to IBM's air emissions during 1987–1993, the public health implications of exposures before 1987 are uncertain. Moreover, the health implications of the combined exposures from the indoor air, outdoor air, and drinking water pathways are uncertain. Therefore, the findings of this health consultation do not diminish the need to consider the historic air exposure pathway in future health studies, if deemed scientifically feasible.

The remainder of this health consultation describes how ATSDR reached these conclusions and summary statements. Persons interested in only a brief summary of the main conclusions and recommendations should refer to the end of this document (see pages 28–30). Those interested in how ATSDR evaluated the available data to develop the conclusions are encouraged to read the entire report. Appendices to this document include a glossary and a more detailed account of the underlying scientific analyses conducted of historic air emissions in the Endicott area.

Note: IBM previously owned and operated multiple facilities in Broome County and in surrounding areas. Unless otherwise stated, all references to "IBM" in this health consultation refer only to the former IBM facility located in Endicott, New York.

Purpose and Statement of Issues

Endicott residents and those of neighboring communities expressed concern to ATSDR and other health agencies about potential health effects that might result from exposure to environmental contamination (NYSDOH, ATSDR, BCHD 2006). This health consultation responds to one particular community concern: the potential for health effects resulting from inhalation of historic outdoor air. After discussing this concern with Endicott residents, ATSDR identified the following objectives for this health consultation:

What Are the Objectives of This Health Consultation?

- To respond to specific community concerns about historic outdoor air emissions from the IBM Endicott facility.

- To determine whether residents were previously exposed to outdoor air pollution at levels that present a public health hazard.

An initial step in ATSDR's work was clearly defining the scope of the evaluation. Listed below are important decisions made about specific issues that this health consultation addresses.

- **What time frame does this health consultation address?** For purposes of this document, "historic" refers to exposures that occurred before 1994, which is the time frame when air emissions from industrial facilities throughout the Endicott area were considerably higher than current levels. Appendix C presents the data ATSDR considered to determine the appropriate time frame to consider for historic emissions. IBM, in consultation with NYSDEC and NYSDOH, is evaluating and investigating current exposures to outdoor air pollution from certain sources, such as operation of sub-slab mitigation systems (NYSDOH, ATSDR, BCHD 2006).

- **Which emissions sources does this health consultation consider?** Community concerns regarding historic air quality focused specifically on IBM's past air emissions of volatile chemicals commonly found in industrial solvents. When gathering data on pollutants that IBM released to the air, ATSDR noted that numerous industrial facilities throughout the Endicott area also released some of the same pollutants. However, because emissions from the IBM facility were notably higher than emissions from other nearby sources (see Appendix C), this health consultation focuses largely on historic air pollution levels caused by IBM's emissions. Air quality impacts from other local air emissions sources are described and characterized, as appropriate. Later sections of this health consultation also acknowledge

that some of the chemicals IBM emitted are also found in various household and consumer products, whose use would add to exposures quantified in this health consultation.

- **Which VOCs does this health consultation address?** The IBM facility previously used hundreds of different chemicals and materials in its manufacturing processes, which led to air emissions of various pollutants. ATSDR used a screening process to identify the VOCs that appear to be of greatest health concern and those for which sufficient information is available to support a rigorous evaluation. These VOCs, referred to in this report as "contaminants of concern," are all chemicals found in industrial solvents that previously were widely used in the microelectronics industry and other industrial sectors. The process ATSDR used to identify contaminants of concern is described later in this health consultation (see Contaminants of Concern, page 13).

- **Which exposure scenarios does this health consultation consider?** This health consultation addresses *environmental* exposures to air pollutants that IBM and other facilities previously released. ATSDR is aware that some residents are also concerned about past *occupational* exposures that occurred at the IBM facility. Occupational exposures are not addressed in this document because ATSDR's mandate does not include evaluating most occupational exposure scenarios. However, the National Institute for Occupational Safety and Health is assessing the feasibility of a study to evaluate associations between health effects and past worker exposures at the IBM facility (NYSDOH, ATSDR, BCHD 2006).

  Furthermore, this health consultation focuses on residents' *direct* inhalation exposures to air pollutants released from the facility. ATSDR also considered *indirect* exposures, or the possibility that air pollutants might have deposited on the ground and then become available for uptake in the food chain (e.g., via fruits and vegetables). However, the contaminants of concern evaluated in this health consultation all are highly volatile and are not expected to be taken up into fruit or garden vegetables in significant amounts (ATSDR 1997a, b; 1999; 2000). Therefore, this document's focus on direct inhalation exposures is appropriate.

The previous discussion describes important decisions that ATSDR made, with community input, when framing the issues to address in this health consultation. The remainder of this health consultation documents how ATSDR evaluated whether residents of the Endicott area were previously exposed to air pollution at levels that present a public health hazard.

Background

ATSDR's approach to evaluating air emissions in Endicott started with collecting background information on topics such as site description, land use, demographics, and meteorology. This section summarizes background information by presenting facts and observations about historical air emissions sources, without analyses or interpretation. Later sections of this report describe how the background information fits into the overall environmental health analysis for the Endicott area.

Site Description and History

Many industrial facilities have been established in the Endicott area, including a wide range of manufacturing and chemical processing operations. Several larger industrial sources[1] that released air pollutants at some time over the past 20 years operated in the vicinity of Endicott (Figure 1, page 45). These facilities include Amerada Hess Corporation, American Board Company, American Manufacturing Services, Amphenol Interconnect Products, Endicott Forging Incorporated, Endicott Johnson Footwear Corporation, Exxon Mobil Oil Corporation, and IBM. ATSDR accessed and reviewed air emissions data for all of these facilities (see Appendix C). Many current and previous smaller industrial and commercial operations have also released air pollutants, but they were not subject to federal emissions reporting requirements. Such operations include automotive repair facilities, dry cleaners, and gasoline stations.

Manufacturing operations at the former IBM facility date back to the early 1900s, at which time International Time Recording Company owned the facility. In 1911, this company merged with two others to form the Computing-Tabulating-Recording Company, which was renamed International Business Machines Corporation (IBM) in 1924. Since the 1940s, the IBM facility manufactured many different microelectronics products, and a main product was integrated

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What Is the Toxics Release Inventory?

Starting in 1987, the U.S. Environmental Protection Agency (EPA) required facilities in certain industries to disclose the amounts of specific toxic chemicals that they release to the environment or manage as waste. The Toxics Release Inventory (TRI) is the publicly accessible database that contains the information submitted by facilities that meet the reporting requirements.

ATSDR often uses TRI data to identify the locations of selected facilities that release toxic chemicals into the environment, but these data have limitations. First, TRI data are self-reported by industry, and the accuracy of these data is not known. Second, while TRI data offer extensive insights into large air emission sources, the data are not comprehensive because of various reporting exemptions. For example, facilities in certain industrial sectors, facilities with fewer than 10 employees, and facilities with relatively small toxic chemical uses are exempt from reporting. Third, TRI data do not break facility-wide emissions down into emissions from individual stacks. In the case of the former IBM facility, ATSDR could only obtain information on the breakdown of emissions across buildings and stacks from air permits and other information provided by NYSDEC.

EPA's Web site on the TRI program (www.epa.gov/tri) presents extensive additional information on the strengths and limitations of using TRI data.

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[1] For purposes of this report, a "larger industrial source" was considered to be any industrial facility with toxic chemical usage quantities large enough to trigger reporting under EPA's Toxic Release Inventory (TRI) program. The paragraph lists all such facilities located within 3 miles of the center of the Village of Endicott.

circuit boards. The production processes used at the facility changed considerably over the years, consistent with advances in the fields of microelectronics, manufacturing technologies, and air pollution controls. IBM continued to operate its microelectronics fabrication processes until 2002, when the Endicott facility was sold to a local business group. Endicott Interconnect Technologies currently conducts business in many of the buildings formerly owned by IBM.

IBM previously used large quantities of solvents in its manufacturing processes. Multiple accounts (e.g., ENSR Consulting and Engineering 1988; 1989; 1991; Roy F. Weston 1991) suggest that solvent usage and emissions were greatest in production buildings nearest where McKinley Avenue passes through the facility, although documented emission sources were located throughout the entire facility (ERG 2004). Although the facility implemented practices to prevent or minimize pollution, IBM released many chemicals into the air. The magnitude of these releases in comparison to other facilities became apparent in the late 1980s, when certain industrial facilities across the country were required to disclose air emissions data to the Toxics Release Inventory (TRI).

The first years of available TRI reporting data showed that the IBM facility led the nation in releases of certain types of air pollutants (USA Today 1989). According to 1988 TRI data, for example, the IBM facility ranked among the nation's top emitters of four VOCs that are considered in this health consultation (EPA 2006a). The 1987 TRI data release was one of the first clear indications that fugitive air emissions (or passive releases that do not occur through stacks) accounted for a considerable portion of IBM's total air releases. The data from the first year of TRI reporting apparently created the incentive for various regulatory actions to reduce emissions.

In the late 1980s, IBM, working in conjunction with the New York State Attorney General's Office and the New York State Department of Environmental Conservation (NYSDEC), developed a plan to reduce its air emissions of certain chemicals. This plan resulted in IBM implementing numerous pollution prevention and source reduction activities, such as replacing some volatile chemicals with nonvolatile substitutes, eliminating uses of certain chemicals, and optimizing processes to prevent leaks and spills (Roy F. Weston, 1991). These and other improvements substantially reduced air emissions from the IBM facility. In fact, based on TRI

Emissions Terminology Used in This Health Consultation

Air-quality specialists use many terms when referring to air emissions from industrial facilities. Definitions of terms used in this health consultation include the following:

- **Emission inventory:** A listing of the amount of air pollutants discharged into the atmosphere. These inventories are usually organized by location, facility, and pollutant. TRI is an example of an emissions inventory.

- **Emission rate:** The amount of air pollutants released by a particular source over a specified time frame. Emission rates from sources are relatively constant throughout a year, while others vary considerably from day to day.

- **Chemical-specific emissions data:** Emissions data for individual chemicals. Such data are required inputs for modeling analyses, such as the one that ATSDR conducted for this site (see Appendix E).

data, the total facility-wide air toxics emissions in 1994 were only 3% of the facility-wide emissions in 1988. (Refer to Appendix C for trends in how IBM's air emission rates changed with time for specific chemicals.)

Land Use and Demographics

Endicott Village is located in the southwest corner of Broome County. According to the 2000 U.S. Census, the village spans 3.14 square miles and has 13,038 residents and 6,686 housing units (Bureau of the Census 2000). The land within Endicott Village has multiple uses, including industrial, commercial, residential, recreational, and agricultural. In the immediate vicinity of the former IBM facility (Figure 2, page 46), however, land uses are primarily commercial and residential. More specifically, residential neighborhoods are located around almost the entire perimeter of the former IBM facility, and numerous homes are located within ½ mile of the buildings that housed IBM's main production operations. A downtown shopping district is located immediately southwest of where McKinley Avenue passes through the former IBM facility; and other commercial land uses nearby include a small shopping mall and numerous businesses along the busier thoroughfares.

An important issue to consider when evaluating outdoor air emissions is how close residents can come to air pollution sources. While trespassing was generally prohibited at the various industrial facilities considered in this evaluation, the sidewalks, streets, and neighborhoods immediately surrounding these facilities were all publicly accessible, and transient exposures likely occurred in such areas. Longer-term exposures most likely occurred in the residential areas throughout Endicott Village. Refer to the Exposure Pathway Evaluation (page 10) for more information on the specific exposure scenarios that this health consultation considers.

Climate and Meteorology

ATSDR reviewed Endicott's climatic and meteorologic conditions, because they affect how air emissions move from their sources to downwind locations. Weather conditions in Broome County vary considerably from one season to the next. For example, according to 30 recent years of weather observations made in Broome County, the monthly average temperature in the area ranges from 21.7 degrees Fahrenheit (^{o}F) in January to 68.7 ^{o}F in July; and the area receives roughly 39 inches of precipitation a year, which includes both rain and snow (NCDC 2002).

Wind speed and wind direction data are collected at multiple locations throughout Broome County, but the most complete and comprehensive data have been collected at the Binghamton Airport. The prevailing wind data from this airport have already been used multiple times to assess air quality impacts from the IBM facility (ENSR Consulting and Engineering 1988, 1989, 1991), including in a recent study that was reviewed and approved by NYSDEC (O'Brien & Gere Engineers 2005). Summaries of the prevailing wind patterns observed at the Binghamton Airport and an evaluation of how representative the airport data are of conditions in Endicott are presented later in this health consultation (see Limitations and Uncertainties, page 17).

Where Can Residents Get More Information on Environmental Health Issues at Endicott?

ATSDR and its partners have evaluated several environmental health issues of concern to Endicott residents. Residents can find more information on these evaluations by

- **Visiting the local records repository.** Selected public health evaluations for the Endicott area may be reviewed, as they become available, at the George F. Johnson Memorial Library, Village of Endicott, 1001 Park Street, Endicott, NY 13760. Please call (607) 757-5350 in advance for library hours and directions.

- **Visiting agency Web sites.** Electronic copies of some public health evaluations are available from the ATSDR Web site (www.atsdr.cdc.gov). In addition, both NYSDEC and NYSDOH maintain Web sites dedicated specifically to environmental health issues for the Endicott area. The addresses for these Web sites are

    NYSDEC: http://www.dec.state.ny.us/website/der/projects/endicott

    NYSDOH: http://www.nyhealth.gov/nysdoh/environ/broome

- **Contacting the agencies directly.** Residents can contact ATSDR (call 1-888-42ATSDR or 1-888-422-8737 and ask for Greg Ulirsch) or NYSDOH (1-800-458-1158, ext. 27530) directly to learn more about previous and ongoing environmental health evaluations specific to the Endicott area.

ATSDR Involvement With the Site

Since the late 1980s, ATSDR and its public health partners have been evaluating several environmental health issues of concern to Endicott residents. The text box at the end of this section describes how residents can get more information on past and ongoing evaluations of issues other than historic outdoor air emissions. Examples of issues that these agencies have addressed are groundwater contamination, drinking water contamination, vapor intrusion into homes from contaminated groundwater, and health statistics. A timeline for the main activities specific to historical outdoor air emissions in the Endicott area follows:

- From June 2004 through October 2005, ATSDR and its contractors conducted multiple file reviews to access background information on the IBM facility and its air emissions. Publicly available files were reviewed at NYSDEC offices in Albany and Syracuse; on two occasions, IBM made selected additional files available for review at its corporate facility in Somers, New York. A summary of information gathered during these file reviews is presented later in this health consultation (see Air Quality Impacts Before 1987: Data Sources, page 12).

- In October 2004, ATSDR attended a meeting in Endicott to summarize information gathered on historic air emissions. The meeting was organized by a local community group, which was then called the Stakeholders Planning Group. (This group is now known as the Western Broome Environmental Stakeholders Coalition [WBESC].)

- In February 2005, ATSDR met with WBESC to provide an update on the ongoing evaluation of historic air emissions. The presentation outlined the approach for using air

dispersion models to estimate air quality impacts associated with the former IBM facility. Options for presenting modeling results were discussed with WBESC members.

- In July 2005, ATSDR met with WBESC to discuss initial modeling results from the evaluation of historic air emissions. The presentation highlighted preliminary findings and acknowledged uncertainties and limitations.

Exposure Pathway Evaluation

This section summarizes how ATSDR evaluated air exposures to historical outdoor air emissions in Endicott. The section presents the exposure assessment methodology, identifies the data sources used to estimate exposures, identifies contaminants of concern and their estimated concentrations, and discusses limitations and uncertainties inherent in this evaluation. This section is intended to provide an overview of the exposure evaluation; the finer technical details of the evaluation are described in the appendixes.

Methodology

A critical element of this health consultation is *exposure*, or how humans come into contact with environmental contaminants. Analyzing exposure is important, because if residents are not exposed to a site's environmental contamination, then the contaminants cannot pose a public health hazard and additional analyses are not necessary. If residents are exposed to site-related contamination, then further analysis is needed to evaluate the exposure. Even if an exposure has occurred, that does not mean the exposed residents will have health effects or get sick. In cases where exposures have occurred, ATSDR considers several questions when determining whether adverse health effects might result:

- To what contaminants are people exposed?

- How often are people exposed, and for how long?

- What are the contamination levels to which people are exposed?

When evaluating sites with outdoor air quality issues, ATSDR needs information on air pollution levels (and how they change with location and time) to answer these questions. ATSDR typically uses two approaches to characterize air pollution levels. One approach is to review air sampling data, or direct measurements of the chemicals in the air that

> **Terminology: "Outdoor" vs. "Ambient"**
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> "Outdoor air" refers to the air that humans breathe outside of buildings. Similarly, "ambient air" also refers to outdoor air, or the outdoor air that surrounds us. This health consultation uses both terms interchangeably. The document refers to "outdoor air emissions," because this phrase is used in the site's Draft Public Health Response Plan. The document also refers to "outdoor air pollution" to distinguish the outdoor air quality issues addressed in this document from indoor air quality issues. Finally, the document refers to "ambient air sampling" and "ambient air concentrations," because air-quality scientists have conventionally used such terms when describing outdoor air pollution levels.

What Are "Air Models"? What Can They Tell Us?

An air model is a mathematical tool that scientists use to estimate how pollutants move through the air, from the point where they are released to locations where people might inhale them. To use air models, information is needed on local weather conditions and the amount of pollutants released into the air. From these and other outputs, models can predict air pollution levels.

Air models are useful because they can estimate air pollution levels for times when and locations where no air samples were collected. Although many models are quite advanced, none are perfect. Because of inherent uncertainties and limitations in our understanding of the atmosphere, air models only offer *estimates* of actual air pollution levels. These estimates could be higher or lower than the actual pollution levels that occurred. The use of rigorous approaches can help minimize modeling uncertainty, but modeling results are not direct measures of air pollution levels. As a result, ATSDR's publications that present modeling data (e.g., this health consultation) usually label results as being *estimates* and comment on the underlying model uncertainties.

humans might have breathed. At the Endicott site, ATSDR found no evidence from all site documents reviewed to date that ambient air sampling ever occurred in the area before 1994, the period of greatest interest for this health consultation. Therefore, air sampling could not be used to quantify past exposures.

The other approach to characterizing air pollution levels is using air models (see text box for more information). Air models are computational tools that *estimate* air pollution levels on the basis of a scientific understanding of how pollutants move through the air. The key inputs to such models are emission rates for the source being evaluated and local weather conditions. After thoroughly reviewing the site documents and other modeling studies of the IBM facility (see Appendix D), ATSDR determined that an air modeling analysis could provide useful insights into past air pollution levels resulting from IBM's emissions. Appendix E documents the air modeling analysis that ATSDR conducted to support the main conclusions of this report.

Air Quality Impacts During 1987–1993: ATSDR's Modeling Analysis

ATSDR's modeling analysis objective was to estimate air pollution levels throughout the Endicott area that resulted specifically from IBM's historic outdoor air emissions. Model outputs therefore characterize the incremental impact of IBM's emissions on air pollution levels, but they do not quantify contributions from other industrial and commercial operations. Furthermore, the model does not try to characterize exposures that might have occurred in indoor settings because of household uses of consumer products containing some of the same contaminants of concern.

ATSDR estimated both short-term and long-term air quality impacts for 14 chemicals that IBM emitted into the air during 1987–1993. Modeling could not estimate air quality impacts for earlier years because of insufficient data. The inability to evaluate air quality before 1987 is an unfortunate limitation; however, relatively few environmental regulations in the United States required industrial facilities to report releases of air pollutants before the late 1980s.

The 14 chemicals considered in this evaluation are those having readily available facility-wide emission rates, which are critical inputs to air modeling studies. The modeling analysis could not

address the numerous additional chemicals that IBM used and released but for which facility-wide emissions data were not available. Nonetheless, ATSDR's model addresses the toxic chemicals that the facility previously released in greatest quantities. More information on the specific chemicals considered for this modeling evaluation follows (see Contaminants of Concern, page 13).

All modeling was conducted using a software program that, at the time ATSDR's project began, EPA had recommended for evaluating complex industrial facilities (e.g., the former IBM site). ATSDR ran the model to predict air quality impacts at locations up to 5 miles away from the IBM facility. The key inputs to the model were emission rates for individual stacks, meteorologic data, and selected user input options. Readers interested in a more detailed account of other aspects of the modeling analysis should refer to Appendix E, which documents all model inputs and presents numerous additional technical details on the modeling approach.

Air Quality Impacts Before 1987: Data Sources for Qualitative Evaluation

As stated earlier, ATSDR could not use models to estimate IBM's air quality impacts before 1987, because the available site records did not document facility-wide emission rates, which are critical inputs to air modeling analyses. Although ATSDR could not quantify pre-1987 air quality impacts associated with the IBM facility, site documents obtained during the file reviews provide some qualitative insights on the time frames when IBM used the various contaminants of concern. The following data sources were considered for this evaluation:

- **Air permitting records.** When conducting file reviews at NYSDEC offices in Albany and Syracuse, New York, ATSDR obtained copies of numerous "certificates to operate," which were essentially state-issued air permits for specific emissions sources at the facility. While the information in these files includes estimates of IBM emissions from individual stacks dating back to the early 1980s, these estimates do not characterize passive releases (or "fugitive emissions") that were known to occur in large quantities elsewhere at the facility. Therefore, the air permitting records offer some insights into chemicals involved in IBM's production processes back to the early 1980s, but these records do not provide a comprehensive account of facility-wide emissions.

- **Review of files made available by IBM.** On two occasions, ATSDR or its contractors reviewed copies of selected files that IBM made available at its corporate office in Somers, New York. The files included reports, letters, orders, and miscellaneous correspondence on various issues, such as purchasing histories and industrial hygiene monitoring. These records did not document facility-wide emission rates before 1987, but they do offer insights on chemical usage during 1965–1968 and 1977–1986. These usage data enabled ATSDR to make some judgments about the duration of potential exposures (see Estimated Ambient Air Concentrations of Contaminants of Concern, page 13), even though the information does not support derivation of quantitative exposure estimates.

Contaminants of Concern

Table 1 (page 37) lists the 14 toxic chemicals that IBM previously used in its processes and for which sufficient information is available to support a quantitative air modeling analysis for 1987–1993. ATSDR used a screening process to identify a subset of these chemicals that warrants more detailed consideration from a health perspective. In this screening process, ATSDR compared the highest estimated ambient air concentration outputs from the modeling analyses with the corresponding chemical-specific comparison values. The comparison values used in this health consultation are ambient air concentrations that are unlikely to cause adverse health effects among exposed persons, and these values are derived from scientific literature concerning exposure and health effects.

To be protective of human health, most comparison values, specifically those for non-cancer health outcomes, have uncertainty factors built into them. For some chemicals, these factors are quite large (e.g., a factor of 100). Due to these protective assumptions, estimated ambient air concentrations at levels lower than their corresponding comparison values are generally considered to have health risks that are very low or minimal. However, the opposite is not true: ambient air concentrations greater than comparison values are not necessarily harmful. Rather, chemicals found at concentrations greater than comparison values require more detailed toxicologic evaluations. In short, comparison values are set at exposure levels that are well below those that cause cancer or non-cancer health effects; ATSDR uses comparison values to identify contaminants of concern, which require more detailed to assess the public health implications of exposure evaluations (see Public Health Implications, page 20). Appendix B lists the specific comparison values used in this health consultation.

Appendix E thoroughly describes how ATSDR applied its process of identifying contaminants of concern and presents the estimated concentrations for all 14 chemicals considered in the modeling. Of these 14 chemicals, three had estimated ambient air concentrations greater than their comparison values. Accordingly, these chemicals—formaldehyde, methylene chloride (MC), and tetrachloroethylene (PCE)—were selected as contaminants of concern for this health consultation. ATSDR also selected trichloroethylene (TCE) as a contaminant of concern because of community concerns specific to this chemical and the evidence ATSDR found that IBM used the chemical in large quantities, especially in the 1960s (ERG 2005b). The remainder of this section briefly summarizes the modeling results for the contaminants of concern, and the following section (Public Health Implications) presents ATSDR's evaluation of the public health implications of exposure to these chemicals.

Estimated Ambient Air Concentrations of Contaminants of Concern

The following paragraphs present the estimated ambient air concentrations that previously resulted from IBM's outdoor air emissions of the four contaminants of concern. The section first describes the rationale for breaking the overall evaluation into different time frames, and then presents the estimated concentrations. For each contaminant of concern, information is presented on estimated long-term and short-term concentrations, exposure durations, and any chemical-specific limitations.

Time Frames of Interest

ATSDR attempted to generate a realistic account of past exposures. One challenge in doing so was that, before 1994, IBM's manufacturing processes and air emissions changed considerably from one year to the next. Furthermore, the information that ATSDR gathered on IBM's past operations was thorough for some years but sparse or nonexistent for others. Overall, the available information supported exposure evaluations for six separate time frames (see Table 2, page 38). For two time frames (i.e., for years before 1965 and for 1969–1976), information is not available to draw qualitative or quantitative conclusions about IBM's air quality impacts. For three time frames (i.e., 1965–1968, 1977–1980, and 1981–1986), the available information supports *qualitative* assessments of air quality impacts, but not quantitative estimates of ambient air concentrations. For another time frame (i.e., 1987–1993), the available data support a *quantitative* air modeling analysis. The following sections present chemical-specific conclusions for these time frames.

Estimated Concentrations of Formaldehyde

Table 3 (see page 39) summarizes the estimated ambient air concentrations of formaldehyde that are attributed to IBM's past emissions. During 1987–1993, the highest estimated annual average concentration (1.4 µg/m^3) was lower than ATSDR's comparison value for non-cancer effects resulting from chronic exposures (10 µg/m^3, see Appendix B); similarly, the highest estimated 24-hour and 1-hour average concentrations (6.6 µg/m^3 and 25 µg/m^3, respectively) were both lower than ATSDR's comparison value for non-cancer effects resulting from acute exposures (50 µg/m^3, see Appendix B). Therefore, the estimated concentrations during 1987–1993 are below levels that would trigger more detailed evaluations for health outcomes other than cancer.

On the other hand, the estimated concentrations attributed to IBM's past emissions for longer durations were higher than the comparison value ATSDR uses when screening data for cancer outcomes (0.08 µg/m^3, see Appendix B). Specifically, during 1987–1993, the highest offsite concentration as a result of IBM's emissions averaged over this 7-year time frame was 1.0 µg/m^3 (equivalent to 0.8 ppb). While IBM clearly emitted formaldehyde before this period, the available information does not support quantitative estimates of the air quality impacts that occurred before 1987.

Because the estimated concentrations exceeded a comparison value for cancer effects, a more detailed assessment of potential cancer risk associated with inhaling formaldehyde was conducted (see Public Health Implications, page 20). However, ATSDR notes that ambient air concentrations of formaldehyde in suburban and urban settings routinely exceed this comparison value as a result of air pollution sources (e.g., motor vehicles and atmospheric decay processes) found throughout the country. According to ambient air monitoring data collected around the country in 1995 and loaded into EPA's Air Quality System database, annual average air concentrations of formaldehyde exceeded the comparison value for cancer endpoints at all 133 stations where this pollutant was measured, including multiple stations in rural settings (EPA 2006b). Thus, while the estimated air concentrations nearest the Endicott facility exceed a comparison value for cancer outcomes and, therefore, require further evaluation, the estimated

concentrations resulting from IBM's emissions do not appear to be elevated in comparison with other U.S. locations.

Estimated Concentrations of Methylene Chloride

Table 4 (see page 40) summarizes estimated ambient air MC concentrations attributed to IBM's past emissions. During 1987–1993, the highest estimated annual average concentration (i.e., 180 $\mu g/m^3$) was lower than ATSDR's comparison value for non-cancer effects resulting from chronic exposures (1,000 $\mu g/m^3$; see Appendix B); similarly, the highest estimated 24-hour average concentration (1,000 $\mu g/m^3$) was lower than ATSDR's comparison value for non-cancer effects resulting from acute exposures (2,000 $\mu g/m^3$, see Appendix B). On the other hand, some estimated 1-hour average concentrations of MC (values up to 4,600 $\mu g/m^3$) exceeded ATSDR's comparison value for non-cancer effects resulting from acute exposure and, therefore, warrant further evaluation (see Public Health Implications, page 20). It should be noted, however, that estimates of 1-hour average concentrations have considerable uncertainties and that ATSDR's modeling estimates likely understate the actual short-term air quality impacts (see Limitations and Uncertainties, page 18, for further discussion).

When screening the estimated concentrations for cancer outcomes, ATSDR noted that the estimated concentrations for longer durations were higher than the corresponding comparison value (3 $\mu g/m^3$, see Appendix B). Specifically, during 1987–1993, the highest offsite concentration as a result of IBM's emissions averaged over this 7-year time frame was estimated to be 51 $\mu g/m^3$ (equivalent to 15 ppb), with the highest level in any given year being 180 $\mu g/m^3$ (equivalent to 52 ppb), which was predicted for 1988.

An important consideration for cancer evaluations is characterizing exposures that occurred over longer time frames. While ATSDR could not use models to estimate air quality impacts for years preceding 1987, the available chemical usage information and air permitting files (see Table 4) strongly suggest that chemical use (and thus, to a first approximation, air emissions) during 1977–1986 were comparable to those that occurred in 1987 and 1988, before IBM began phasing out its MC uses. Based on this analysis, the highest estimated long-term average offsite MC concentration reasonably supported by the available information for the 17-year time frame (1977–1993) would be 120 $\mu g/m^3$ (equivalent to 35 ppb).[2] While exposures may have occurred for longer time frames (i.e., before 1977), the nature and extent of IBM's air quality impacts preceding 1977 cannot be assessed from the available information.

The previous discussion addresses how estimated MC concentrations varied with time at a single location (i.e., the offsite location predicted to have the highest air quality impacts). Figure 3 (see page 47) provides some perspective on how the estimated concentrations varied with location. In general, and as expected, the highest estimated concentrations attributed to IBM's emissions occurred closest to the facility and then decreased sharply with distance. Specifically, the highest estimated offsite concentration was predicted to occur at the facility fence line, and estimated concentrations at locations 1 mile away from the facility were more than 10 times lower than the

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[2] This value was calculated for 1977–1993. The estimated concentrations from the modeling analysis were used in this calculation for 1987–1993. Concentrations for 1977–1986 were estimated as the average IBM-related air quality impacts predicted for 1987 and 1988.

highest predicted value. According to U.S. Census demographic data, ATSDR estimated that approximately 7,200 persons lived in the area marked "highest concentrations" in Figure 3; 7,000 residents lived in the area marked "moderate concentrations;" and 27,800 residents lived in the area marked "lower concentrations."

As noted previously, ATSDR's modeling analysis only considered the incremental effects that IBM's air emissions had on local air quality. Although other industrial facilities in the Endicott area used and emitted MC, the available information strongly suggests that IBM's emissions accounted for the overwhelming majority of MC released into the air from industrial facilities in the Endicott area (see Appendix C). Accordingly, the estimated concentrations from the model provide reasonable accounts of the overall air quality impacts for this chemical, particularly in the immediate vicinity of the IBM facility. The Public Health Implications section of this health consultation comments on how the estimated ambient air concentrations of MC near the IBM Endicott facility compare with levels measured elsewhere in the United States.

Estimated Concentrations of Tetrachloroethylene (PCE)

Table 5 (see page 41) summarizes estimated ambient air PCE concentrations attributed to IBM's past emissions. During 1987–1993, the highest estimated annual average concentration (25 $\mu g/m^3$) was lower than ATSDR's comparison value for non-cancer effects resulting from chronic exposures (300 $\mu g/m^3$, see Appendix B); similarly, the highest estimated 24-hour and 1-hour average concentrations (95 $\mu g/m^3$ and 370 $\mu g/m^3$, respectively) were both lower than ATSDR's comparison value for non-cancer effects resulting from acute exposures (1,000 $\mu g/m^3$; see Appendix B). Therefore, the estimated concentrations during 1987–1993 are below levels that would trigger more detailed evaluations for health outcomes other than cancer.

When screening the estimated concentrations for cancer outcomes, ATSDR noted that the estimated concentrations for longer durations were higher than the corresponding comparison value (2 $\mu g/m^3$; see Appendix B).[3] Specifically, during 1987–1993, the highest offsite concentration as a result of IBM's emissions averaged over this 7-year time frame was an estimated 13 $\mu g/m^3$ (equivalent to 1.9 ppb), with the highest level in any given year being 25 $\mu g/m^3$ (equivalent to 3.6 ppb), which was predicted for 1988.

An important consideration for cancer evaluations is characterizing exposures that occurred over longer time frames. Although ATSDR could not use models to estimate air quality impacts for years preceding 1987, the available chemical usage information and air permitting files (see Table 5) strongly suggest that PCE chemical use (and thus, to a first approximation, air emissions) during 1977–1986 were greater than the chemical use that occurred in 1987 and 1988, when IBM began phasing out its use of many organic solvents. On the basis of this evaluation, ATSDR can approximate air quality impacts for a 17-year time frame. The highest estimated long-term average offsite PCE concentration that is reasonably supported by the available

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[3] The comparison value used to evaluate cancer endpoints for PCE is based on a "unit risk factor" (see Glossary) that EPA had previously reported for this chemical. EPA now notes that the unit risk factor for PCE is under review and the outcome of this evaluation is pending. ATSDR used the previous unit risk factor for this initial screening analysis. The Public Health Implications evaluation of PCE is based on a much broader review of the health effects literature for this chemical.

information for the period 1977–1993 is 18 μg/m^3 (equivalent to 2.7 ppb).[4] Whether PCE exposures occurred before this time frame is unclear, because none of the records ATSDR accessed document PCE usage or emissions at IBM before 1977.

The previous discussion addresses how estimated PCE concentrations varied with time at a single location (i.e., the offsite location predicted to have the highest air quality impacts). Figure 4 (see page 48) provides some perspective on how estimated PCE levels varied with location. In general, and consistent with observations for MC, the highest estimated PCE concentrations attributed to IBM's emissions occurred closest to the facility and then decreased sharply with distance. Specifically, the highest estimated offsite concentration was predicted to occur at the facility fence line, and estimated concentrations at locations 1 mile away from the facility were more than 10 times lower than the highest predicted value. Using U.S. Census demographic data, ATSDR estimated that approximately 2,600 persons lived in the area marked "highest concentrations" in Figure 4. Approximately 5,500 residents lived in the area marked "moderate concentrations," and 22,700 residents lived in the area marked "lower concentrations."

As noted previously, ATSDR's modeling analysis only considered the incremental impacts that IBM's air emissions had on local air quality. Although other industrial facilities and commercial operations (e.g., dry cleaners) in the Endicott area used and emitted PCE, the available information strongly suggests that IBM's emissions accounted for the overwhelming majority of PCE released into the air by large industrial facilities in the Endicott area (see Appendix C). Accordingly, the estimated concentrations from the model provide reasonable accounts of the overall air quality impacts for this chemical, particularly in the immediate vicinity of the IBM facility. The Public Health Implications section of this health consultation comments on how the estimated ambient air concentrations of PCE near the IBM Endicott facility compare with levels measured elsewhere in the United States.

Estimated Concentrations of Trichloroethylene (TCE)

Because facility-wide emissions data for TCE are not documented in any of the available reports, ATSDR could not use models to estimate offsite air quality impacts associated with IBM's operations. The lack of emissions data appears to result from the fact that IBM had largely phased out its TCE uses by the year (1987) when toxic chemical emissions reporting was first required at the federal level. Thus, approximately 20 years have elapsed since the time frame when IBM largely phased out its major TCE uses, although ongoing exposures might be occurring as a result of other sources (e.g., vapor intrusion from contaminated groundwater).

Nonetheless, the information that ATSDR accessed provides some interesting perspective on the time frames when TCE was used in greatest amounts (see Table 6, page 42). For example, air permit records for 1981–1986 suggest that stack emissions of TCE were considerably lower than other organic solvents IBM used at the time (e.g., MC and PCE) and that TCE emissions had decreased substantially by the mid-1980s. Records obtained during a file review (ERG 2005b) indicated that annual TCE usage during 1977–1979 was, on average, 500,000 pounds per year.

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[4] This value was calculated for 1977–1993. The estimated concentrations from the modeling analysis were used in this calculation for 1987–1993. Concentrations for 1977–1986 were estimated as the average IBM-related air quality impacts predicted for 1987 and 1988.

This usage is considerably lower than the usage data documented for other solvents (e.g., MC and PCE), which IBM used in quantities greater than 2,000,000 pounds per year during the same time frame. To a first approximation (i.e., if chemical usage data is assumed to be roughly proportional to air emissions), the offsite air quality impacts of TCE during 1977–1993 can be assumed to be lower than those documented for other solvents (e.g., MC and PCE), although a precise estimate of TCE concentrations cannot be made because of the lack of emissions data.

One distinguishing aspect of past TCE use is the significant quantities that IBM used in the late 1960s. Specifically, site records for 1965–1968 suggest that IBM used approximately 7,350,000 pounds of TCE per year (ERG 2005b). This average annual usage rate exceeds those for all other chemicals and for all other years for which usage data were available. Thus, it appears that the greatest TCE exposures occurred during 1965–1968, although ATSDR cannot rule out the possibility that comparable or even higher exposures occurred in other years for which records are not available (i.e., for years preceding 1965 and for 1969–1976).

Limitations and Uncertainties

Dispersion modeling for complex facilities, such as the former IBM facility, has many inherent uncertainties and limitations. Uncertainty in dispersion modeling comes from various sources. For instance, although models may reflect the state of science on air dispersion, no model perfectly represents our atmosphere. Even in cases where all model inputs have been extremely well characterized, estimated concentrations still can overstate or understate actual air quality impacts. Dispersion modeling predictions tend to be most accurate for estimating long-term (e.g., annual average) air quality impacts, with the predictive ability of most models decreasing with shorter averaging periods. For short-term impacts, models can adequately predict the magnitude of peak concentrations when inputs are appropriately characterized, but the models tend to perform less well in predicting exactly when and where the highest short-term concentrations would have occurred.

Uncertainty also is introduced into modeling studies because of the assumptions made in the modeling approach and the values selected for model inputs. Appendix E presents a detailed review of uncertainty in the dispersion modeling analysis, with the following two important sources of uncertainty:

- A critical model input is the amount of chemicals that the former IBM facility released into the air, because any error in the emission rates used as model inputs results in errors in the model outputs. While the accuracy of the emissions data cannot be quantified from the available information, ATSDR limited its modeling analyses to only those chemicals having facility-wide emissions data of a perceived high quality. The quality of these data was assessed largely through judgment, considering observations such as concordance of emissions estimates among multiple site-related documents. Multiple documents that IBM officials certified as being accurate included reasonable, consistent facility-wide air emissions rates for the time frame that was modeled.

  Though the annual emissions data input into ATSDR's modeling analysis are believed to be reasonably accurate, uncertainties are far greater for the short-term modeling

predictions. This is because no detailed site-specific data are available to quantify actual peak emissions, which were likely driven by process upsets, spills, leaks, and other unplanned or episodic events. Moreover, no scientifically defensible approaches are available to estimate short-term peak emissions rates that might have occurred at IBM in the past. As a result, the short-term modeling results only reflect fluctuations in meteorologic conditions and do not account for short-term peak emissions that undoubtedly occurred. The net result of this approach is that the modeling predictions likely understate actual short-term air quality impacts that occurred around the facility.

- Modeling analyses, such as the one done by ATSDR, typically require 5 consecutive years of high-quality meteorologic data as a model input. After identifying various sources of meteorologic data for Broome County and consulting with dispersion modeling experts, ATSDR chose to base its modeling analysis on meteorologic data collected at the Binghamton Airport. These data were judged to be the most representative, accurate, and complete data set that could be used in the modeling analysis, even though prevailing wind patterns at the airport likely differ to a certain extent from those near the former IBM facility. Use of the airport's meteorologic data introduces uncertainty in the modeling analysis, but the magnitude of this uncertainty cannot be quantified. (Note, as Appendix D explains, ATSDR has accessed and reviewed multiple other air modeling studies specific to the IBM facility, and each one of these studies also used meteorologic data from Binghamton Airport as a model input.) If 5 consecutive years of site-specific meteorologic had been available, ATSDR believes the magnitudes of offsite concentrations would likely have been reasonably consistent with those predicted in the modeling analysis used in this health consultation; however, the locations of greatest air quality impacts might have differed somewhat (i.e., the shape of the concentration contours in Figures 3 and 4 might have been different).

ATSDR acknowledges uncertainty in the modeling primarily and emphasize that the results presented in this health consultation are estimates and are not direct measurements of past ambient air concentrations. However, the aforementioned sources of uncertainty are not unique to the IBM Endicott facility and are frequently encountered in site-specific dispersion modeling projects. Overall, ATSDR's position is that it would be appropriate to characterize the modeling results presented in this health consultation as the agency's best estimates of past air quality impacts resulting from IBM's air emissions during 1987–1993. These estimates are based on scientifically rigorous modeling approaches and underlying data, but they may still understate or overstate actual air quality impacts that might have occurred.

The previous discussion focuses on uncertainties. ATSDR's modeling analysis also has several limitations, which result from how the project scope was defined early in this assessment. For instance, the modeling is limited in terms of temporal coverage. The modeling provides detailed insights on air quality impacts, but only for the years (i.e., 1987–1993) for which we have sufficient data to support a defensible evaluation. Furthermore, the modeling addresses 14 chemicals, which is a small subset of the number of chemicals that IBM previously used. However, this evaluation focused on the chemicals believed to be of greatest interest because of their toxicity and emission rates and those for which available information was judged sufficient to support modeling. Additionally, the modeling predicts the incremental effect that IBM's past

emissions had on local air quality. Actual air pollution levels were likely higher than those predicted by the modeling, due to contributions from other outdoor sources (although the emissions data in Appendix C demonstrates that the modeling evaluation considered the largest of the major industrial sources in the Endicott area). Overall, none of these limitations necessarily weakens the modeling analysis, but the limitations are important to acknowledge such that modeling results are interpreted in the proper context.

Summary of Exposure Pathway Evaluation

In review, air quality impacts were estimated for 14 chemicals that IBM previously used and emitted into the air. The modeling was conducted only for the years 1987–1993, because insufficient information is available to support a thorough modeling analysis for earlier years. The following subset of chemicals is addressed further in the Public Health Implications section of this document for the reasons listed:

- **Formaldehyde and PCE.** Estimated ambient air concentrations at some offsite locations exceeded health-based comparison values for cancer endpoints, but not for non-cancer endpoints. Thus, further evaluation is needed only for potential cancer risks associated with past exposures to formaldehyde and PCE.

- **MC.** Estimated ambient air concentrations at some offsite locations exceeded health-based comparison values for cancer endpoints and for acute non-cancer endpoints (but not for chronic non-cancer endpoints). The next section of this health consultation revisits these endpoints.

- **TCE.** ATSDR could not estimate past ambient air concentrations of TCE from the available information. However, further information on TCE is presented in the following section given community concerns specific to this chemical.

For all other chemicals considered, the estimated ambient air concentrations were all below their corresponding health-based comparison values, as Appendix E notes. Though these chemicals did not warrant further consideration due to their *individual* toxicities, ATSDR did follow its current chemical mixtures guidance to evaluate the health implications exposures to groups of chemicals *combined*.

Public Health Implications

The following section evaluates the public health implications of exposure to historic air emissions from the IBM facility; this evaluation is based on the worst-case exposure scenario developed from the computer modeling performed by ATSDR. That is, the public health implications are based on the levels of exposure for a receptor just outside the IBM fence line. The risk for an adverse health effect to most of the population in the maximally exposed areas (2,600–7,200 persons; see Figures 3 and 4) would be less than for the maximally exposed persons just outside the IBM fence line.

Because contact rates (i.e., breathing rates) are different for children and adults, cancer risks during the first 30 years of life were calculated using age-adjusted factors. These factors approximated the integrated exposure from birth until age 30 years by combining contact rates, body weights, and exposure durations for two age groups—small children and adults (EPA, 2006). Cancer risks were calculated using these factors and were based on combined childhood and adult exposure. Therefore, the estimated theoretical cancer risks presented below for each contaminant of concern are for both adults and children.

The lifetime cancer risks (based on exposure for 24 hours/day, 7 days/week, for 70 years) were calculated from the following equation (EPA 2006):

$$\text{Cancer risk} = \frac{C_{air} \text{ X } EF_r \text{ X } IF_{adj} \text{ X } CSF_i}{AT_c \text{ X } CF}$$

      where:

C_{air} = average concentration of contaminant in air ($\mu g/m^3$)
EF_r = exposure frequency (days/year) = 365 days/year
IF_{adj} = age-adjusted inhalation factor (m^3-year/kg-day) = 11.66
CSF_i = cancer slope factor for inhalation
AT_c = averaging time carcinogens (days) = 25,550 days for 70 years exposure
CF = conversion factor = 1,000 $\mu g/mg$

Historic Air Exposures to Formaldehyde

Formaldehyde is naturally produced in very small amounts in our bodies as part of our normal, everyday metabolism. It can also be found in the air that we breathe at home and at work, in the food that we eat, and in some products that we put on our skin. A major source of formaldehyde that we breathe every day is found in smog in the lower atmosphere. Formaldehyde is also contained in exhaust from cars that do not have catalytic converters and from cars that use oxygenated gasoline. At home, formaldehyde is produced by cigarettes and other tobacco products, gas cookers, and open fireplaces. It is also used as a preservative in some foods, such as some types of Italian cheeses, dried foods, and fish. Formaldehyde is found in many products used every day around the house, such as antiseptics, medicines, cosmetics, dishwashing liquids, fabric softeners, shoe-care agents, carpet cleaners, glues and adhesives, lacquers, paper, plastics, and some types of wood products. Some people are exposed to higher levels of formaldehyde if they live in a new mobile home, because formaldehyde is given off as a gas from the manufactured wood products used in these homes (ATSDR, 1999).

As previously indicated, formaldehyde was selected for further evaluation based on the average exposure level for 1987–1994 exceeding the health comparison value for cancer. Moreover, neither short-term nor longer-term average concentrations of formaldehyde exceeded any non-cancer health screening values. Therefore, non-cancer adverse health effects are not expected based on available information from the computer air modeling and are not further discussed.

Several studies of laboratory rats exposed for life to high amounts of formaldehyde in air found that the rats developed cancer of the nasal cavity. Some studies of humans exposed to lower amounts of formaldehyde in the workplace found more cases of cancer of the nasal cavity and throat than expected, but other studies have not found throat cancer in other groups of workers exposed to formaldehyde. Therefore, formaldehyde is considered to a probable human carcinogen by EPA based on limited human data and sufficient animal data (ATSDR, 1999).

The estimated average formaldehyde concentration that an Endicott resident living near the IBM fence line was exposed to during 1987–1993 was 1.0 $\mu g/m^3$. From a risk standpoint, if persons were exposed to this level for 70 years, we may theoretically see an additional seven cancer cases for every one million persons exposed. However, we were only able to estimate exposure levels for the 7-year period from 1987 through 1993; therefore, based on this duration of exposure, we may see less than one additional cancer case for every one million persons exposed to these levels. These risk estimates are based on mathematical models because the actual risk of long-term, low-level exposures to formaldehyde is not known. In the scientific literature, actual cancer effect levels found are much higher than the exposure levels we estimated in the highest exposed areas of Endicott (12,500–18,750 times higher). Therefore, based only on estimated long-term exposures to formaldehyde from 1987–1994, the cancer risk is likely to be very low.

Historic Air Exposures to Methylene Chloride (MC)

MC is widely used as an industrial solvent and as a paint stripper. It can be found in certain aerosol and pesticide products and is used in the manufacture of photographic film. The chemical may be found in some spray paints, automotive cleaners, and other household products. MC does not appear to occur naturally in the environment. Most of the MC in the environment results from its use as an end product by various industries and the use of aerosol products and paint removers in the home (ATSDR 2000).

As previously indicated, MC was selected for further evaluation because of the likelihood that the average exposure level for a 7-year time frame from1987 through 1993 exceeded the cancer health comparison value. Maximum estimated exposures to long-term and shorter-term (1–14 days) levels of MC in the Endicott community were below health screening levels for non-cancer effects. As such, non-cancer adverse health effects are not expected for exposures occurring during this time frame based on available information from the computer air modeling and are not further discussed. However, MC levels for time periods of less than 1 day (1 hour) possibly were above non-cancer health screening values for non-cancer effects; however, as previously indicated, ATSDR is very uncertain about the accuracy of this 1-hour value because computer modeling for shorter time frames of exposure is very uncertain. Both cancer and non-cancer (for short-term exposures of less than 24 hours) adverse health effects are evaluated below.

ATSDR identified in the scientific literature several animal and human studies in which the exposure durations were between 10 minutes and about 4 hours (ATSDR 2000). ATSDR identified two studies where serious (among monkeys; Heppel et al. 1944) and less serious (among humans; Putz et al. 1979) neurologic effects were found. However, the estimated maximum 1-hour exposure level to persons living near the former IBM plant was 154 and 7,692 times, respectively, below the lowest levels that indicated a less serious or serious adverse health

effect in these studies. Therefore, it is unlikely that the estimated short-term exposure levels (if exposed for 4 or fewer hours) would have resulted in any serious adverse health effects in the Endicott community.

The evidence is unclear regarding whether MC causes cancer in humans exposed to vapors in the workplace. However, breathing high concentrations of MC for long periods of time did increase the incidence of cancer in mice. The U.S. Department of Health and Human Services (DHHS) has determined that MC may reasonably be anticipated to be a cancer-causing chemical. The International Agency for Research on Cancer (IARC) has classified MC as possibly causing cancer in humans (IARC 1986). EPA has determined that MC is a probable cancer-causing agent in humans (ATSDR 2000).

Although we are more certain about the long-term levels of exposure to Endicott residents from 1987 through 1993 (51 µg/m^3), as previously indicated, some available information indicates that the emissions of MC from IBM during 1977–1986 were similar to those during 1987 and 1988. The estimated average concentration of MC that Endicott residents living near the IBM fence line were exposed to during 1977–1993 was 120.0 µg/m^3. From a risk standpoint, if persons were exposed to this level for 70 years, we may theoretically see an additional three cancer cases among every 100,000 persons exposed. However, only rough estimates of exposure levels could be derived for the 17-year period from 1977 through 1993; therefore, on the basis of this duration of exposure, we may theoretically see an additional eight cancer cases among every 1,000,000 persons exposed to these levels. These risk estimates are based on mathematical models because the actual risk for long-term, low-level exposures to MC is unknown. Actual cancer effect levels found in the scientific literature are much higher than the exposure levels we estimated in the highest exposed area just outside the IBM fence line (4,100–16,667 times higher). Therefore, based only on estimated long-term exposures to MC during 1977–1993, the cancer risk is likely to be low to very low. The excess lifetime cancer risk for persons exposed to the levels of MC estimated during the 1987–1993 time frame would be lower than for the cancer risks for the 1977–1993 exposure time frame and would also be characterized as very low to low.

Historic Air Exposures to Tetrachloroethylene (PCE)

Tetrachloroethylene (PCE) is a synthetic chemical widely used for dry cleaning of fabrics and for metal-degreasing operations. It is also used as a starting material (building block) for making other chemicals and is used in some consumer products. People can be exposed to PCE from environmental and occupational sources and from consumer products. Consumer products that might contain PCE include water repellents, silicone lubricants, fabric finishers, spot removers, adhesives, and wood cleaners. When clothes are brought home from the dry cleaners, the clothes may release small amounts of PCE into the air (ATSDR 1997a).

As previously indicated, PCE was selected for further evaluation based on the likelihood that the average exposure level for a 7-year timeframe from 1987 through 1993 exceeded the cancer health comparison value. Maximum estimated exposures to long-term and shorter-term levels of PCE in the Endicott community were below health screening levels for non-cancer effects. As such, non-cancer adverse health effects are not expected based on available information from the

computer air modeling and are not further discussed. Therefore, only cancer adverse health effects are evaluated below.

Results of animal studies show that exposure to high levels of PCE can cause liver and kidney damage and liver and kidney cancer even though the relevance to people is unclear. Although it has not been shown to cause cancer in humans, the Department of Health and Human Services (DHHS) has determined that PCE may reasonably be anticipated to be a cancer causing chemical. The International Agency for Research on Cancer (IARC) has determined PCE probably causes cancer in humans (ATSDR, 1997a).

We are more certain about the long-term levels of exposure to residents of Endicott for the time frame from 1987–1993 (13 µg/m^3). There is some information that IBM PCE emissions from 1977–1986 may have been higher than for 1987 and 1988; however, we do not have sufficient information to quantify exposures for this period. If we assume that exposures for 1977–1986 were similar to 1987 and 1988, then the estimated average concentration of PCE that a resident of Endicott could have been exposed to during 1977–1993 was 18.0 µg/m^3. From a risk standpoint, if persons were exposed to this level for 70 years, we may theoretically see an additional six cancer cases for every 100,000 persons exposed. However, we were only able to roughly estimate exposure levels for the 17 year period from 1977–1993; therefore, based on this duration of exposure, we may theoretically see an additional one cancer case for every 100,000 persons exposed to these levels. These risk estimates are based on mathematical models since we do not know the actual risk of long-term, low-level exposures to PCE. Actual cancer effect levels found in the scientific literature are much higher than the exposure levels we estimated in the highest exposed area of Endicott just outside the IBM fence line (214,000-297,777 times higher). Therefore, based only on estimated long-term exposures to PCE from 1977–1993, the cancer risk is likely to be low. The excess cancer risk for persons exposed during the 1987–1993 timeframe would be slightly less than for the 17-year timeframe from 1977 through 1993 and still considered to be low. It is important to note that the risks calculated for exposure to PCE were based on an inhalation cancer slope factor (CSF) developed by California EPA. The inhalation CSF for PCE is being reviewed by the US EPA; however, as an interim approach, US EPA Superfund program is using the number developed by California EPA (EPA, 2003).

Historic Exposures to Trichloroethylene (TCE)

Trichloroethylene is now mainly used as a solvent to remove grease from metal parts. It is also used as a solvent in other ways and is use to make other chemicals. Trichloroethylene can also be found in some household products, including typewriter correction fluid, paint removers, adhesives, and spot removers. The biggest source of TCE in the environment is from evaporation from factories that use it to remove grease from metals.

It is uncertain whether people who breathe air containing TCE are at a higher risk for cancer. In studies using high doses of TCE in rats and mice, tumors in the lungs, and testes were found, providing some evidence that high doses of TCE can cause cancer in experimental animals. Based on limited data in humans regarding TCE exposure and cancer, and evidence from high doses of TCE can cause cancer in animals, the International Agency for Research on Cancer

(IARC) has determined that TCE is probably carcinogenic to humans. However, more studies are needed to establish the relationship between TCE exposure and cancer (ATSDR, 1997).

As previously indicated, we were not able to estimate the levels of exposure to TCE in the air around the former IBM plant. However, ATSDR believes that persons were not likely exposed to high levels of TCE after IBM began phasing out its use in the mid-1980s. It is likely that the highest exposures to TCE from the IBM plant occurred before 1987 and especially from 1965-1968 where we were able to determine that TCE usage and emissions, and therefore exposure, was probably higher than what ATSDR predicted for PCE, MC, or formaldehyde. However, again, ATDSR cannot predict what that exposure may have been and if these higher levels occurred at other timeframes before 1965 and between 1969 and the mid-1980s.

Evaluating Health Effects From Exposure to Multiple Chemicals

The health impact of exposure to chemical mixtures can be of particular concern at hazardous waste sites because most such sites contain multiple chemical contaminants. Evaluation of chemical mixtures especially must consider potential toxic interactions at environmentally relevant doses of chemicals. However, relatively few studies have assessed toxic interactions in these low dose ranges. A series of important studies on the toxicity of low-dose chemical mixtures was conducted by a nutritional and food research institute in the Netherlands. These studies found no discernable toxic response until the dose levels of the individual chemicals approached or exceeded their individual thresholds. However, when the chemicals were administered at their individual LOAEL doses, additive toxic effects clearly were evident. Furthermore, additive toxicity was observed even though the chemicals had different mechanisms of toxicity (ATSDR 2005).

Other studies have provided evidence that exposure to chemical mixtures, in which the chemicals were administered at doses near their individual thresholds, can produce additive toxic effects. However, no evidence exists of additive toxicity from exposure to chemical mixtures when the individual chemicals are administered at doses well below their individual thresholds. Nevertheless, the threshold doses (i.e., levels at which adverse health effects have not been observed) for many toxic endpoints in animals are not well defined. Therefore, considering the potential for toxic effects from exposure to chemical mixtures at all sites is prudent (ATSDR 2004).

Sometimes a mixture of chemicals might act in a greater than additive manner, which is referred to as a synergistic effect or synergism. When two chemicals are acting synergistically, one chemical is enhancing the effect of the other chemical. Mathematically, a chemical mixture with a synergistic effect is often presented as $2 + 3 = 8$ (or 6 or 12, depending on how strong the synergistic effect is between the two chemicals.) If a mixture contains two chemicals that interact synergistically, the health scientist knows that the possible adverse health effects for those two chemicals is greater than simply adding the risk for the individual chemicals.

A chemical mixture that acts in a less-than-additive manner, this is referred to as an antagonistic effect. In this case, one of the chemicals is reducing the effect of the other chemical. Stated another way, one chemical is protecting against the effect of another chemical. An antagonistic

effect might be presented mathematically as 2 + 3 = 4. If a mixture contains two chemicals that interact in an antagonistic manner, the health scientist knows that the possible adverse health effects for those two chemicals, is less than simply adding the individual risk for each chemical.

The health scientist first reviews the individual inhalation Hazard Quotient or HQ (see below for how the HQ is calculated) for each chemical. ATSDR's mixture guidance states that if all the inhalation HQs for each chemical is less than 0.1, then interactions between the chemicals in the mixture are unlikely. Stated another way, the chemical mixture will not have any significant interactions (either additive, synergistic, or antagonistic) if each of the individual oral HQs are less than 0.1. ATSDR's mixtures guidance also states that if only one HQ exceeds 0.1, then interactions between that chemical and other chemicals in the mixture are unlikely (ATSDR, 2004a).

The formula for determining the inhalation HQ for a chemical follows:

$$\text{Inhalation HQ}_{\text{individual chemical}} = \text{The Estimated Air Exposure Level} \div \text{Health Guideline}$$

For the three chemicals of concern (formaldehyde, MC and PCE), ATSDR calculated individual HQs for both chronic and acute exposures. ATSDR used the highest estimated annual average concentration predicted for any given year (from 1987 to 1993) to calculate the individual HQs for long-term exposures. Furthermore, we used the highest estimated 24-hour average concentration (for short-term exposures) predicted from the computer model and not the 1-hour estimated concentration because of the high uncertainty of the accuracy of this number. Based on this evaluation, individual HQs, for both long-term and short-term exposures were above 0.1 for two of the three chemicals (see table below); therefore, further evaluation was necessary.

Calculation of HQs and HIs for Chemicals of Concern to Evaluate Possible Mixtures Effects (see notes on following page)

Chemical of Concern	Highest Daily Concentration (1987–1993) ($\mu g/m^3$)	Highest Yearly Concentration (1987–1993) ($\mu g/m^3$)	ATSDR Minimum Risk Level (MRL) ($\mu g/m^3$)	Hazard Quotient	
				Acute[a]	Chronic[b]
Formaldehyde	6.6	1.4	50 (A)	0.13	0.14
			10 (C)		
Methylene Chloride	1,000	180	2,000 (A)	0.50	0.18
			1,000 (C)		
Tetrachloroethylene	95	25	1,000 (A)	0.10	0.08
			300 (C)		
HI[c]				0.73	0.40

Notes:
HQ – Hazard quotient
HI – Hazard index
A - Acute MRL
C - Chronic MRL
a - Acute HQ = Highest Daily Concentration ÷ Acute MRL
b - Chronic HQ = Highest Yearly Concentration ÷ Chronic MRL
c - HI = Total HQs for either acute or chronic effect

The next step in the process was to determine if there is any evidence in the scientific literature of synergistic non-cancer effects to air exposures containing the mixture of formaldehyde, MC, and PCE. Based on a review of ATSDR's Toxicological Profiles for PCE, MC, and formaldehyde, there is no indication that the combination of exposure to any one of these contaminants with another would increase the risk of non-cancer effects above what might be expected based on exposure to that individual chemical. Therefore, the next step was to add the individual HQs to determine the Hazard Index, as follows:

Inhalation $HI_{mixture}$ = inhalation $HQ_{chemical\ one}$ + inhalation $HQ_{chemical\ two}$ + inhalation $HQ_{chemical\ three}$

Whenever an HI for a mixture of chemicals is less than 1, adverse health effects from exposure to the mixture are unlikely. ATSDR calculated the HI for long-term exposures (HI = 0.4) and for short-term (1-day) exposures (HI = 0.73) and determined them to be less than 1. Therefore, ATSDR does not expect to see adverse non-cancer effects because of the exposure to the mixture of air contaminants emitted from IBM for the exposures that occurred during 1987–1993. However, much is uncertain regarding the levels of air contaminants before 1987, particularly in the 1970s, 1960s, and earlier. For example, ATSDR has information that TCE air emissions from IBM from 1965–1968 may have been greater than the air quality impacts predicted for all other chemicals and timeframes. Because we cannot predict the exposure concentrations to TCE and other air contaminants during these earlier timeframes, we cannot say with certainty that individual toxic thresholds or the mixture of these individual exposures were not at levels of health concern before 1987.

A review of ATSDR's Toxicological Profiles for PCE, MC, and formaldehyde shows no indication that the combination of exposure to any one of these contaminants with another would increase the risk for cancer above what might be expected based on exposure to that individual chemical. Therefore, we can assume that the total cancer risk is additive. If persons were exposed to mixture of formaldehyde, PCE, and MC for their entire lifetimes, at the levels estimated, we may theoretically see less than one additional cancer case among every 10,000 persons exposed. These risk levels are still considered to be low.

Child Health Considerations

In communities faced with air contamination, the many physical differences between children and adults demand special emphasis. Children could be at greater risk than are adults from certain kinds of exposure to hazardous substances. Some children are outdoors longer than adults, which can increase their exposure potential to poor air quality. Also, a child's lower body weight results in a greater dose of hazardous substance per unit of body weight. If toxic exposure levels are high enough during critical growth stages, the developing body systems of children can sustain permanent damage. Finally, children are dependent on adults for access to housing, for access to medical care, and for risk identification. Thus, adults need as much information as possible to make informed decisions regarding their children's health.

The health screening values used to evaluate whether a particular chemical in the air was at levels of concern for non-cancer adverse health effects were developed to be protective of children. In addition, the cancer risk estimates did include factors that adjusted for contact rates, body weights, and exposure duration for children. Therefore, we do not expect any non-cancer adverse health effects in children for exposures to IBM air emissions during 1987–1993. Moreover, a child's exposure to IBM air emissions for this same timeframe would likely result in a very low to low risk for cancer.

Conclusions

- **Estimated exposures.** No outdoor air pollution measurements were made in Endicott before 1994, and measurements cannot be made now to characterize past air pollution levels. Consequently, ATSDR used a computer model to estimate how air emissions from the former IBM facility affected local air quality. The model estimates a facility's air quality impacts on the basis of the amounts of chemicals released into the air, local weather conditions, and a scientific understanding of how pollutants move through the air. Modeling could not be conducted for years preceding 1987 because of the lack of chemical-specific emissions data. During 1987–1993, the extent to which the IBM facility affected air quality varied with location, time, and chemical. The areas with the highest air quality impacts generally were closest to the center of previous production operations (i.e., nearest where McKinley Avenue passes through the former facility), and impacts attributed to the IBM facility decreased considerably with downwind distance. Additionally, air quality impacts attributed to IBM decreased substantially in the late 1980s, as the facility began to phase out many of its toxic chemical uses. The following conclusions are based on the past estimated ambient air concentrations (1987–1993) that likely resulted specifically from the former IBM facility's outdoor air emissions.

- **Potential for non-cancer effects (1987–1993).** ATSDR determined, on the basis of a worst-case estimated exposure to a person living just outside the fence line at the former IBM facility, that past exposures (during 1987–1993) to VOCs emitted in the air were not like likely to have resulted in non-cancer adverse health effects. All of the estimated

long-term (greater than 1 year) and shorter-term (1–14 days) exposures were well below levels that reportedly have caused adverse health effects in animals or humans. However, although there is great uncertainty, it is possible that the levels of MC, for time periods of less than 1 day (1 hour), may have been above health screening values for non-cancer effects. ATSDR further evaluated these past exposures by comparing the estimated 1-hour MC air concentration to results from animal and human studies to MC for similar time frames. We determined that the estimated past exposure levels among persons living near the former IBM plant were below those that are likely to have resulted in serious adverse non-cancer health effects in either adults or children.

- **Potential for cancer effects (1987–1993).** ATSDR also evaluated the risk for cancer in the worst-case estimated exposure scenario (i.e., exposure to a person living just outside the fence line at the former IBM facility). Three air contaminants—formaldehyde, MC, and PCE—were above conservative health screening values for cancer effects and were further evaluated. For the time frame 1987–1993, we determined that both adult and childhood exposures from IBM air emissions to these three chemicals would have likely resulted in a very low to low excess risk for cancer (ranging from greater than one theoretical cancer case for every million persons exposed to less than one theoretical cancer case for every 10,000 persons exposed). The risk for an adverse health effect to most of the population in the maximally exposed areas (i.e., 2,600–7,200 persons) would be less than for the maximally exposed persons just outside the IBM fence line.

- **Exposure to chemical mixtures (1987–1993).** ATSDR also evaluated the possible health effects of exposure to the combined mixture of VOCs historically emitted from the IBM plant. ATSDR's approach to evaluating exposure to multiple chemicals is based on evidence in the scientific literature that exposure to several chemicals at the same time is not likely to result in non-cancer adverse health effects if the levels of the individual chemicals are well below their health-effect thresholds. Because none of the estimated short-term (1-day maximum) or long-term air contaminant concentrations were near or above their respective individual non-cancer thresholds, adverse non-cancer effects from exposure to multiple chemicals are not expected. For cancer effects, no information in the scientific literature indicates that cancer effects for the combined exposures to formaldehyde, MC, and PCE are more than what would be expected by adding the risks of exposure to each one individually. The combined cancer risk associated with past exposure to formaldehyde, MC, PCE, and other VOCs among persons who lived near the former IBM plant during 1987–1993 is likely to be low.

- **Overall conclusion and hazard category.** ATSDR has determined, after evaluating the possible past air exposures to VOCs emitted at the former IBM plant and the possible health effects in persons (both adults and children) living near the plant during 1987–1993, that these exposures presented no apparent public health hazard. Although ATSDR evaluated MC and PCE exposures for a longer period (1977–1993), much information is uncertain because exposure levels for years preceding 1987 could not be estimated from the computer modeling. Moreover, ATSDR cannot be certain about exposure levels to TCE that may have been greater than the exposures to formaldehyde, MC, and PCE for certain time frames. Because of insufficient data, the public health implications of air

exposures from the IBM plant before 1987 cannot be determined; therefore, ATSDR has categorized exposure that occurred in this earlier time frame as an indeterminate public health hazard.

Public Health Action Plan

New York State Department of Health (NYSDOH) and ATSDR determined that certain cancers and adverse birth outcomes were elevated in an area where indoor air exposures to VOCs were possible (ATSDR 2006). NYSDOH and ATSDR are currently assessing the feasibility of conducting a follow-up epidemiologic study based on the findings from this evaluation. The expected release to the public of the feasibility assessment results is fall of 2006. If a more rigorous analytical study is warranted, a follow-up study for the Endicott area would need to consider the multiple exposure pathways that may have been present (such as indoor air, ambient air, drinking water, and occupational pathways), as well as other risk factors for each of the health outcomes (such as smoking or socioeconomic status). The feasibility of conducting an in-depth follow-up study will depend in part on the quality of environmental information available for estimating potential or actual exposures for individuals or individual households.

Even though ATSDR determined that adverse health effects were unlikely for persons who were exposed to air emissions from the IBM facility during 1987–1993, much information is uncertain regarding the public health implications of exposures before 1987. Moreover, much is uncertain regarding the health implications of combined exposures from the indoor air, outdoor air, and drinking water. Therefore, the findings of this health consultation do not diminish the need to consider, if deemed scientifically feasible, the historic air exposure pathway in future health studies.

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Tables

Table 1. Toxic Chemicals Considered in ATSDR's Modeling Analysis

1,2-Dichlorobenzene	Methanol	tert-Butyl alcohol
Ethylbenzene	2-Methoxyethanol	Tetrachloroethylene (PCE)
Ethylene glycol	Methylene chloride (MC)	1,1,1-Trichloroethane (TCA)
Formaldehyde	Methyl ethyl ketone	Xylenes
Freon 113	Phenol	

Note: This table reports commonly used names for the chemicals that ATSDR considered in its evaluation. Many of these chemicals are also referred to by other names. For example, freon 113 is also known as 1,1,2-trichloro-1,2,2-trifluoroethane, and tetrachloroethylene is also known as perchloroethylene. The table also notes abbreviations of chemicals (MC, PCE, and TCA) that are used in this health consultation.

This table does not provide a complete inventory of the toxic chemicals that the International Business Machines Corporation (IBM) used at its facilities. Rather, the chemicals listed above were the toxic chemicals that the facility used in large enough quantities to trigger reporting to the U.S. Environmental Protection Agency's Toxics Release Inventory (TRI) for some year during 1987–1993. The other chemicals that IBM used during this same time frame presumably did not require TRI reporting (e.g., the chemical was not listed among those requiring reporting, or the chemical was not used in quantities large enough to trigger reporting).

Table 2. Time Frames of Interest for the Exposure Evaluation

Years	Approach and Data Sets Used to Characterize Exposures
Before 1965	None of the records ATSDR accessed provided insight on the International Business Machines Corporation (IBM's) operations, chemical usage, or emissions during this time frame. Accordingly, no conclusions can be drawn for exposures preceding 1965.
1965–1968	During a file review (ERG 2005b), ATSDR identified several letters that documented consumption of cleaning solvents for a department at the IBM Endicott facility. The letters reported the following: annual chemical usage rates for several contaminants of concern for 1965 and 1966, usage rates for several contaminants of concern for one quarter in 1967, and annual usage rates for one contaminant of concern for 1968. These records did not document estimated emission rates.
1969–1976	None of the records ATSDR accessed provided insight on IBM's operations, chemical usage, or emissions during this period. Accordingly, no conclusions can be drawn for exposures during 1969–1976.
1977–1980	During a file review (ERG 2005b), ATSDR identified multiple "Industrial Chemical Surveys" prepared by IBM that documented annual chemical usage rates for selected contaminants of concern during 1977–1980. In a different file review (ERG 2005c), ATSDR identified purchasing records for some of these same contaminants. However, none of these records included estimated emission rates.
1981–1986	During a file review (ERG 2005c), ATSDR identified purchasing records for several contaminants of concern. In addition, ATSDR obtained copies of relevant air permitting records when reviewing files at the New York State Department of Environmental Conservation. The permitting files included estimated air emissions from stack sources, but not from fugitive sources. None of the records ATSDR reviewed reported facility-wide air emission rates.
1987–1993	Facility-wide air emissions data for this period are documented in many references (e.g., [EPA] U.S. Environmental Protection Agency 2006a). With these data and other types of information, ATSDR could use air models to estimate air quality impacts from IBM's past operations.

Table 3. Estimated Air Concentrations for Formaldehyde

Years	Estimated Ambient Air Concentrations
Before 1965	None of the records ATSDR accessed documented the International Business Machines Corporation (IBM's) chemical usage or emissions of formaldehyde during these years. IBM's boilers likely emitted formaldehyde as a combustion byproduct during this time frame, but the amount of formaldehyde released cannot be estimated from the available data. Therefore, ATSDR cannot quantitatively or qualitatively assess the extent to which IBM's operations contributed to offsite air quality impacts of formaldehyde before the 1980s.
1965–1968	
1969–1976	
1977–1980	
1981–1986	Some air permits on file at the New York State Department of Environmental Conservation document releases of formaldehyde from certain sources at IBM, but these records do not include estimated releases from fugitive sources. Without facility-wide air emissions data, ATSDR cannot quantitatively assess IBM's air quality impacts of formaldehyde during this period. The only inference that should be made is that IBM released formaldehyde during this period, but the magnitude of the facility's air quality impacts is not known.
1987–1993	ATSDR's modeling analysis generated the following estimated concentrations of formaldehyde. These concentrations were predicted to occur at the offsite location with the highest air quality impacts, which is along the property line of the former IBM facility. Estimated ambient air concentrations at all other offsite locations are lower than the values listed below. Note that every estimated concentration represents only the incremental air quality impacts attributed to IBM's former operations. This estimate likely understates actual concentrations, because motor vehicles, other combustion sources, and natural sources in the Endicott area also released formaldehyde into the air. The estimated concentrations are as follows: • Estimated average concentration over entire 7-year period: 1.0 µg/m^3 (0.8 ppb) • Highest estimated annual average concentration: 1.4 µg/m^3 (1.2 ppb) • Highest estimated 24-hour average concentration: 6.6 µg/m^3 (5.4 ppb) • Highest estimated 1-hour average concentration: 25 µg/m^3 (20 ppb)

Abbreviations: µg/m^3 = micrograms per cubic meter; ppb= parts per billion.

Table 4. Estimated Air Concentrations for Methylene Chloride (MC)

Years	Estimated Ambient Air Concentrations
Before 1965	None of the records ATSDR accessed provided insights on the International Business Machines Corporation's (IBM's) operations, chemical usage, or emissions of MC during these years. Accordingly, no conclusions can be drawn for exposures preceding 1965.
1965–1968	Data collected during a file review (ERG 2005b) suggest that annual MC usage during this period varied considerably, from at least 200,000 pounds per year (in 1967) to at least 1,100,000 pounds per year (in 1965). The reason for this variability is unclear. Regardless, ATSDR cannot estimate ambient air concentrations from the usage data, and no estimates of facility-wide air emissions were located for these years.
1969–1976	None of the records ATSDR accessed provided insights on IBM's operations, chemical usage, or emissions of MC during these years. Accordingly, no conclusions can be drawn for exposures during this period.
1977–1980	Information collected during a file review (ERG 2005b) suggests that IBM's annual usage rate of MC during this time frame was 2,175,000 pounds per year. Emission rates cannot be calculated directly from this average usage rate. However, because MC did not enter IBM's products in appreciable quantities, a substantial fraction of the MC used likely was eventually emitted into the air. Therefore, the air emissions of MC during 1977–1980 conceivably were not unusually higher or lower than those that IBM reported for 1987 and 1988 (i.e., before the facility began phasing out MC uses).
1981–1986	The air permit files that ATSDR reviewed include stack emissions data for MC for numerous sources across the facility. Total annual MC emissions calculated from these permit files for 1981–1986 are relatively consistent with total annual MC emissions calculated from the permits for the years 1987 and 1988. This observation suggests that the air quality impacts estimated for 1987 and 1988 may be reasonably representative of those that occurred during 1981–1986. However, ATSDR could not conduct modeling for 1981–1986 because of the lack of fugitive emissions data.
1987–1993	ATSDR's modeling analysis generated the following estimated concentrations of MC. These concentrations were predicted to occur at the offsite location with the highest air quality impacts, which is along the property line of the former IBM facility. Estimated ambient air concentrations at all other offsite locations are lower than the values listed below. Note that every estimated concentration represents only the incremental air quality impacts attributed to IBM's former operations. This estimate likely understates actual concentrations, because some other sources in the Endicott area also released MC into the air; however, emissions from the former IBM facility were apparently far greater than those from all other local facilities combined (see Appendix C). The estimated concentrations are as follows: • Estimated average concentration over entire time frame: 51 µg/m^3 (15 ppb) • Highest estimated annual average concentration: 180 µg/m^3 (52 ppb) • Highest estimated 24-hour average concentration: 1,000 µg/m^3 (300 ppb) • Highest estimated 1-hour average concentration: 4,600 µg/m^3 (1,300 ppb)

Abbreviations: µg/m^3 = micrograms per cubic meter; ppb= parts per billion.

Table 5. Estimated Air Concentrations for Tetrachloroethylene (PCE)

| Years	Estimated Ambient Air Concentrations
Before 1965	None of the records ATSDR accessed provided insights on the International Business Machines Corporation's (IBM's) operations, chemical usage, or emissions of PCE during these years. Accordingly, no conclusions can be drawn for exposures before 1965.
1965–1968	Records identified during a file review reflect uses of multiple chlorinated solvents during these years, but PCE was not listed in the inventory. Possible explanations for this are that a) IBM was not using PCE during this time or b) the records ATSDR reviewed were incomplete. In either case, without usage or emissions data, ATSDR could not estimate ambient air concentrations of PCE for this period.
1969–1976	None of the records ATSDR accessed provided insights on IBM's operations, chemical usage, or emissions of PCE during this time frame. Accordingly, no conclusions can be drawn for PCE exposures for this period.
1977–1980	Information collected during a file review (ERG 2005b) suggests that IBM's annual PCE usage rate during this period was 2,300,000 pounds per year. Emission rates cannot be calculated directly from this average usage rate. However, because PCE did not enter IBM's products in appreciable amounts, a substantial fraction of the PCE used likely was eventually emitted into the air. Even if only 10% of the PCE used during this period was emitted, the facility-wide emission rates would have exceeded those reported during any year from 1987 through 1993. Thus, offsite ambient air PCE concentrations during 1977–1980 resulting from IBM's air emissions were likely greater than those estimated for 1988–1993, although this cannot be substantiated with modeling results.
1981–1986	The air permit files that ATSDR reviewed included stack emissions data for PCE for numerous sources across the facility. Total annual PCE emissions calculated from these files for 1981–1986 were at least twice as high as the total annual PCE emissions calculated from the 1987–1988 permits, suggesting that the air quality impacts estimated for 1987 and 1988 were likely less than those that occurred for 1981–1986. However, ATSDR could not conduct modeling estimate PCE concentrations for 1981–1986 because of the lack of fugitive emissions data.
1987–1993	ATSDR's modeling analysis generated the following estimated concentrations of PCE. These concentrations were predicted to occur at the offsite location with the highest air quality impacts, which is along the property line of the former IBM facility. Estimated ambient air concentrations at all other offsite locations are lower than the values listed below. Note that every estimated concentration represents only the incremental air quality impacts attributed to IBM's former operations. This estimate likely understates actual concentrations, because other sources in the Endicott area also released PCE into the air. The estimated concentrations are as follows: • Estimated average concentration over entire 7-year period: 13 $\mu g/m^3$ (1.9 ppb) • Highest estimated annual average concentration: 25 $\mu g/m^3$ (3.6 ppb) • Highest estimated 24-hour average concentration: 95 $\mu g/m^3$ (14 ppb) • Highest estimated 1-hour average concentration: 370 $\mu g/m^3$ (55 ppb)

Abbreviations: $\mu g/m^3$ = micrograms per cubic meter; ppb= parts per billion.

Table 6. Estimated Air Concentrations for Trichloroethylene (TCE)

Years	Estimated Ambient Air Concentrations
Before 1965	None of the records ATSDR accessed provide insights on the International Business Machines Corporation's (IBM's) operations, chemical usage, or emissions of TCE during this time frame. Accordingly, no conclusions can be drawn for exposures preceding 1965.
1965–1968	Data collected during a file review (ERG 2005b) suggest that the facility used at least 7,350,000 pounds of TCE per year during this time frame. This annual usage rate is greater than the annual usage rates that ATSDR identified for all other toxic chemicals and time frames considered in this evaluation. Thus, to a first approximation (i.e., emissions being roughly proportional to usage), it is reasonable to assume that IBM's air quality impacts of TCE during these years might have exceeded the air quality impacts predicted for all other chemicals and time frames. However, the available information is not sufficient to support a quantitative estimate of ambient air concentrations for these years.
1969–1976	None of the records ATSDR accessed provided insights on IBM's operations, chemical usage, or emissions of TCE during this time frame. Accordingly, no conclusions can be drawn for exposures during 1969–1976.
1977–1980	Data collected during a file review (ERG 2005b) suggest that IBM's annual usage rate of TCE during this time frame was 500,000 pounds per year, which is more than 10 times lower than the amounts used in the late 1960s. This information suggests that the facility had already begun phasing out its TCE uses. Without information on emission rates, ATSDR could not estimate ambient air concentrations for this period.
1981–1986	Air permit records provide quantitative estimates of IBM's stack emissions of TCE during this period, but no data on fugitive emissions were available. According to the permits, IBM's stack emissions of TCE were considerably lower than stack emissions for other chemicals, and TCE usage apparently decreased substantially by 1986. These findings are generally consistent with other observations suggesting that IBM had phased out most of its TCE uses in the mid-1980s. As with the other time frames, ATSDR could not estimate ambient air concentrations because of the lack of facility-wide emissions data.
1987–1993	No TCE emissions data are available for this time frame, presumably because IBM's uses of TCE had fallen below levels that would have required the facility to disclose air emissions to the U.S. Environmental Protection Agency's Toxics Release Inventory. As a result, ambient air concentrations could not be estimated for this period.

Figures

Figure 1. Selected Current and Former Industrial Air Emission Sources Near the Former International Business Machines Corporation (IBM) Facility in the Village of Endicott, Town of Union, in Broome County, New York
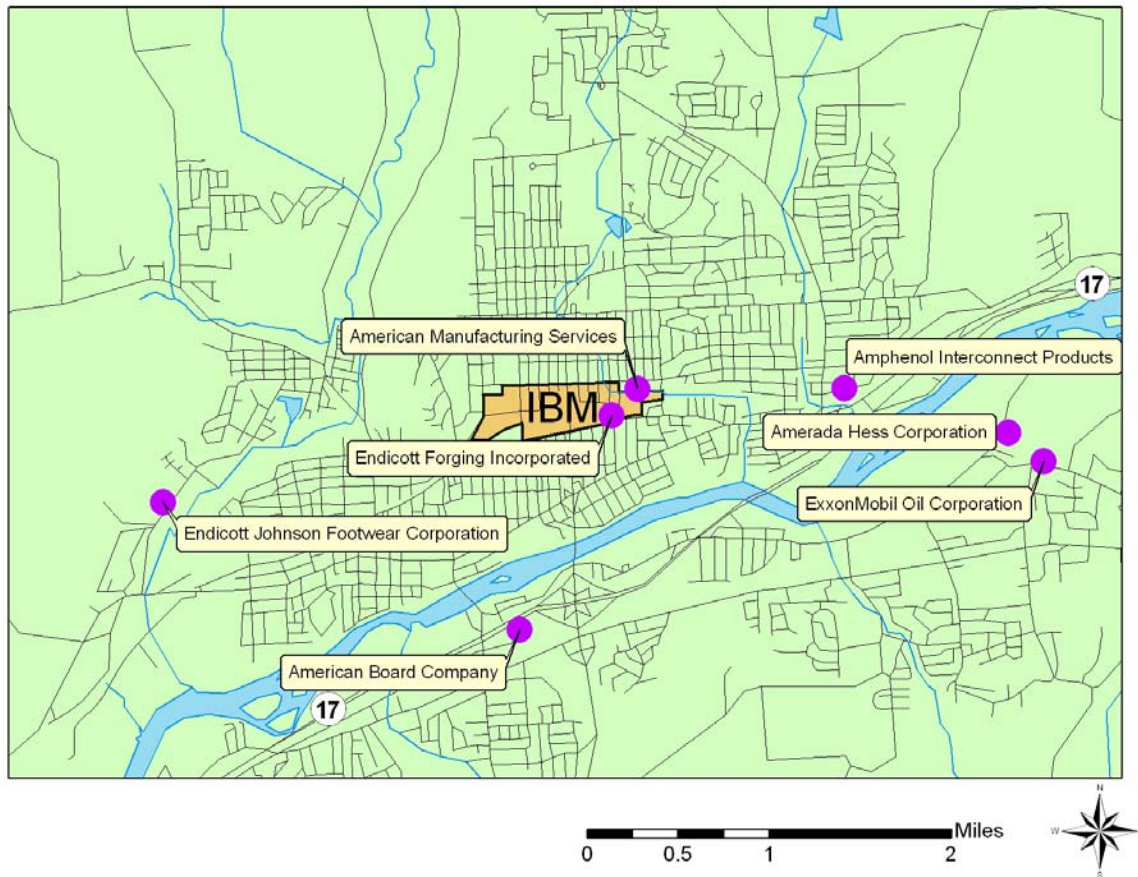
Notes: This figure shows the locations of industrial facilities located within 3 miles of the IBM Endicott facility that disclosed air emissions data to the U.S. Environmental Protection Agency's (EPA's) Toxics Release Inventory (TRI) at some time from 1987 to the present. While this area was home to industrial and commercial air pollution sources in addition to those shown here, the facilities identified in this figure are the subset that use (or previously used) toxic chemicals in quantities large enough to trigger TRI reporting.

The facility locations shown on the map are based on addresses and geographic coordinates (latitude and longitude) reported by the individual facilities; some error might have occurred in the reporting.

Source of data: EPA 2006a.

Figure 2. Immediate Vicinity of the Former International Business Machines Corporation (IBM) Facility in the Village of Endicott, Town of Union in Broome County, New York

Note: This figure shows the immediate vicinity of the IBM facility, with approximate locations of selected buildings that housed IBM's former production, administrative, and other operations. The figure does not display every building at the former facility.

Figure 3. Spatial Extent of Estimated Ambient Air Concentrations of Methylene Chloride (MC) in 1988 at the Former International Business Machines Corporation (IBM) Facility in the Village of Endicott, Town of Union in Broome County, New York
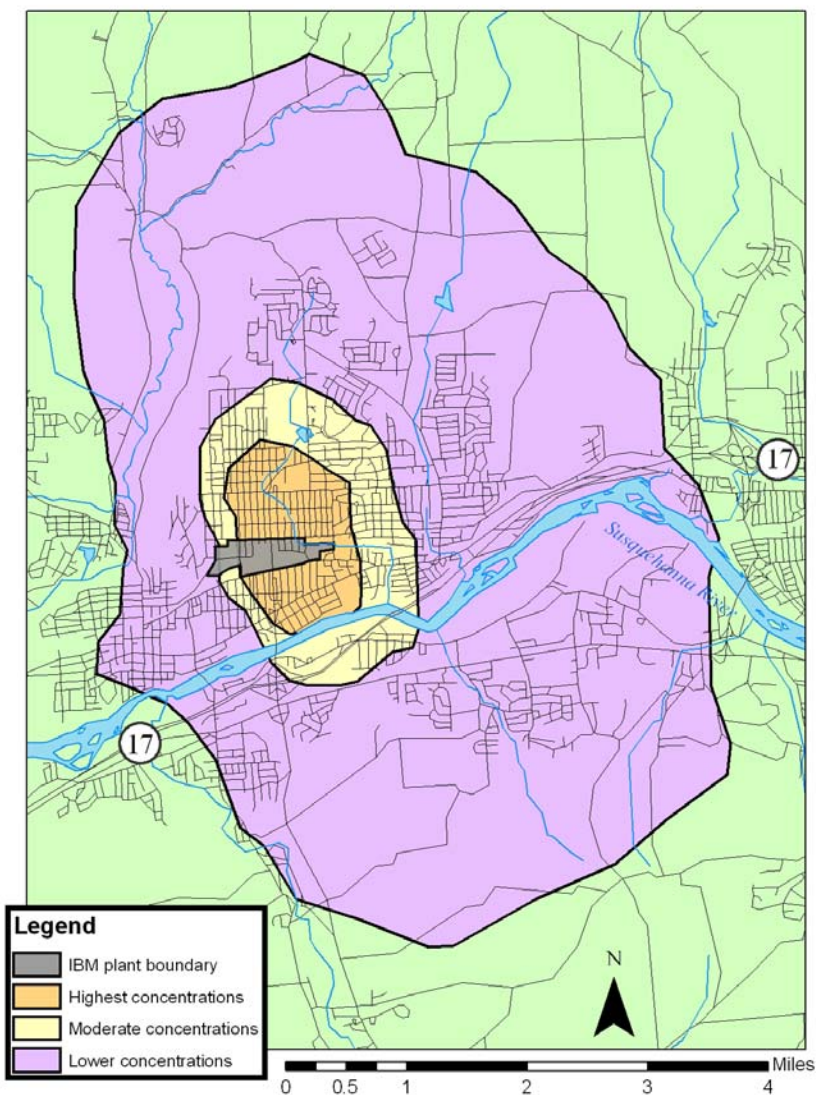
Notes: This figure depicts estimated outdoor air quality impacts resulting from the facility's releases of MC. The figure does not account for MC that might have been released from other industrial, commercial, or residential sources. Refer to Public Health Implications (page 20) for ATSDR's health interpretations of this information.

This figure qualitatively shows how the past air quality impacts likely decreased as the distance from the facility increased. In 1988, the areas marked "highest concentrations" had estimated average concentrations that were greater than approximately 20 micrograms per cubic meter (μg/m^3). The areas marked "moderate concentrations" had estimated values of approximately 10–20 μg/m^3. The areas with "lower concentrations" had estimated values of approximately 2–10 μg/m^3.

Figure 4. Spatial Extent of Estimated Ambient Air Concentrations of Tetrachloroethylene (PCE) in 1988 at the Former International Business Machines Corporation (IBM) Facility in the Village of Endicott, Town of Union in Broome County, New York
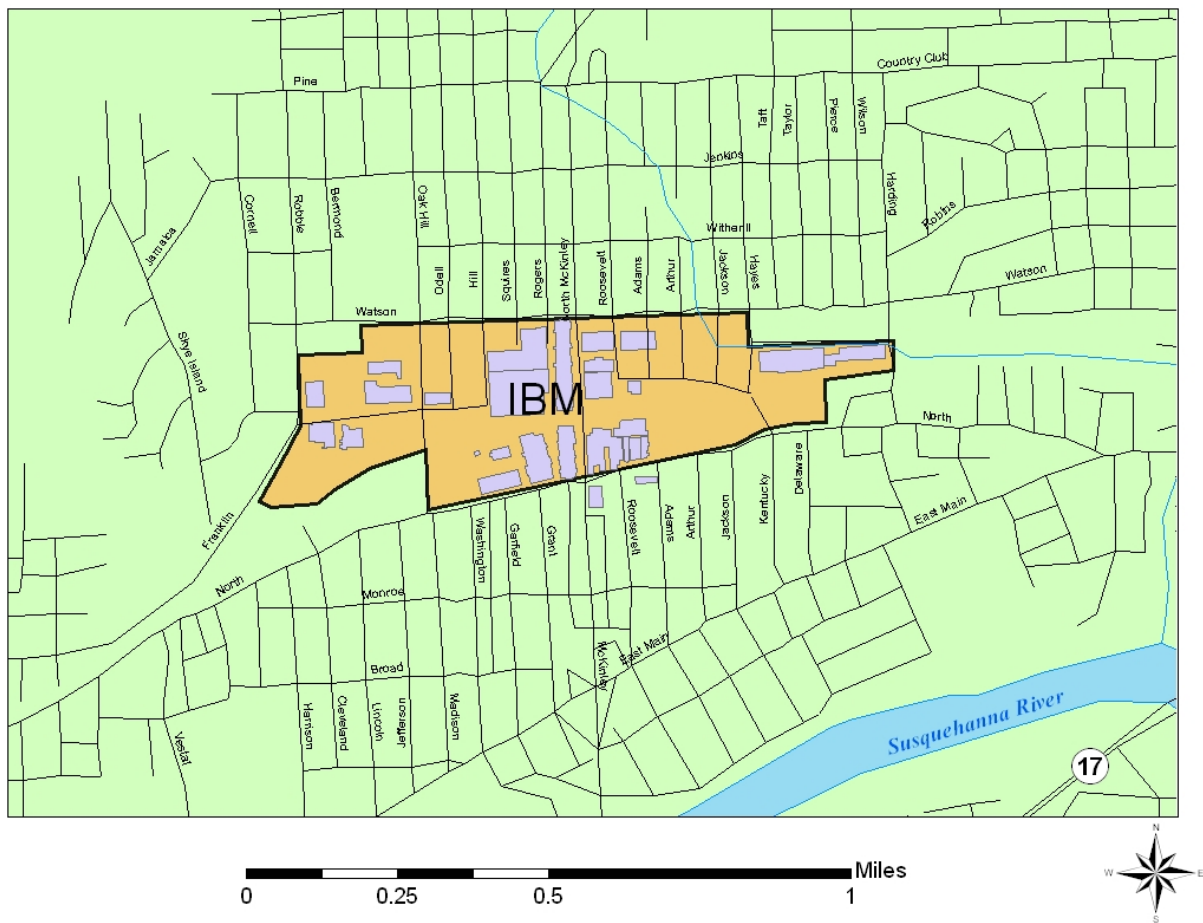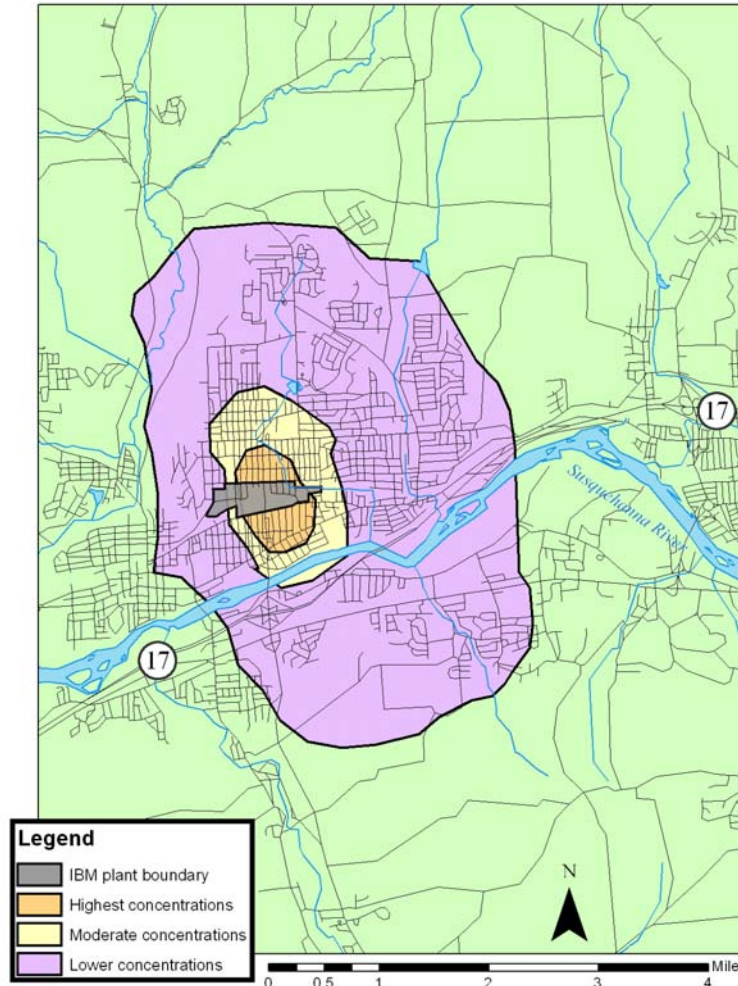
Notes: The figure depicts estimated outdoor air quality impacts that resulted from the former IBM facility's releases of PCE. The figure does not account for PCE that might have been released from other industrial, commercial, or residential sources. Refer to Public Health Implications (page 20) for ATSDR's health interpretations of this information.

The figure is intended to show qualitatively how past air quality impacts likely decreased as the distance from the facility increased. In 1988, the areas marked "highest concentrations" had estimated annual average concentrations greater than approximately 2.5 μg/m^3. The areas marked "moderate concentrations" had estimated values of approximately 1.2–2.5 μg/m^3. The areas with "lower concentrations" had estimated values of approximately 0.2–1.2 μg/m^3.

Appendix A. ATSDR Glossary of Terms

The Agency for Toxic Substances and Disease Registry (ATSDR) is a federal public health agency with headquarters in Atlanta, Georgia, and 10 regional offices in the United States. ATSDR's mission is to serve the public by using the best science, taking responsive public health actions, and providing trusted health information to prevent harmful exposures and diseases related to toxic substances. ATSDR is not a regulatory agency, unlike the U.S. Environmental Protection Agency (EPA), which is the federal agency that develops and enforces environmental laws to protect the environment and human health. This glossary defines words used by ATSDR in communications with the public. It is not a complete dictionary of environmental health terms. If you have questions or comments, call ATSDR's toll-free telephone number, 1-888-42-ATSDR or (1-888-422-8737).

General Terms

Absorption
The process of taking in. For a person or an animal, absorption is the process of a substance getting into the body through the eyes, skin, stomach, intestines, or lungs.

Acute
Occurring over a short time [compare with chronic].

Acute exposure
Contact with a substance that occurs once or for only a short time (up to 14 days) [compare with intermediate duration exposure and chronic exposure].

Additive effect
A biologic response to exposure to multiple substances that equals the sum of responses of all the individual substances added together [compare with antagonistic effect and synergistic effect].

Adverse health effect
A change in body function or cell structure that might lead to disease or health problems

Aerobic
Requiring oxygen [compare with anaerobic].

Ambient
Surrounding (for example, ambient air).

Anaerobic
Requiring the absence of oxygen [compare with aerobic].

Analyte
A substance measured in the laboratory. A chemical for which a sample (such as water, air, or blood) is tested in a laboratory. For example, if the analyte is mercury, the laboratory test will determine the amount of mercury in the sample.

Analytic epidemiologic study
A study that evaluates the association between exposure to hazardous substances and disease by testing scientific hypotheses.

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Antagonistic effect
A biologic response to exposure to multiple substances that is less than would be expected if the known effects of the individual substances were added together [compare with additive effect and synergistic effect].

Background level
An average or expected amount of a substance or radioactive material in a specific environment, or typical amounts of substances that occur naturally in an environment.

Biodegradation
Decomposition or breakdown of a substance through the action of microorganisms (such as bacteria or fungi) or other natural physical processes (such as sunlight).

Biologic indicators of exposure study
A study that uses (a) biomedical testing or (b) the measurement of a substance [an analyte], its metabolite, or another marker of exposure in human body fluids or tissues to confirm human exposure to a hazardous substance [also see exposure investigation].

Biologic monitoring
Measuring hazardous substances in biologic materials (such as blood, hair, urine, or breath) to determine whether exposure has occurred. A blood test for lead is an example of biologic monitoring.

Biologic uptake
The transfer of substances from the environment to plants, animals, and humans.

Biomedical testing
Testing of persons to find out whether a change in a body function might have occurred because of exposure to a hazardous substance.

Biota Plants and animals in an environment. Some of these plants and animals might be sources of food, clothing, or medicines for people.

Body burden
The total amount of a substance in the body. Some substances build up in the body because they are stored in fat or bone or because they leave the body very slowly.

CAP [see Community Assistance Panel.]

Cancer
Any one of a group of diseases that occur when cells in the body become abnormal and grow or multiply out of control.

Cancer risk
A theoretical risk for getting cancer if exposed to a substance every day for 70 years (a lifetime exposure). The true risk might be lower.

Carcinogen
A substance that causes cancer.

Case study
A medical or epidemiologic evaluation of one person or a small group of people to gather information about specific health conditions and past exposures.

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Case-control study
A study that compares exposures of people who have a disease or condition (cases) with people who do not have the disease or condition (controls). Exposures that are more common among the cases may be considered as possible risk factors for the disease.

CAS registry number
A unique number assigned to a substance or mixture by the American Chemical Society Abstracts Service.

Central nervous system
The part of the nervous system that consists of the brain and the spinal cord.

CERCLA [see Comprehensive Environmental Response, Compensation, and Liability Act of 1980]

Chronic
Occurring over a long time [compare with acute].

Chronic exposure
Contact with a substance that occurs over a long time (more than 1 year) [compare with acute exposure and intermediate duration exposure]

Cluster investigation
A review of an unusual number, real or perceived, of health events (for example, reports of cancer) grouped together in time and location. Cluster investigations are designed to confirm case reports; determine whether they represent an unusual disease occurrence; and, if possible, explore possible causes and contributing environmental factors.

Community Assistance Panel (CAP)
A group of people from a community and from health and environmental agencies who work with ATSDR to resolve issues and problems related to hazardous substances in the community. CAP members work with ATSDR to gather and review community health concerns, provide information on how people might have been or might now be exposed to hazardous substances, and inform ATSDR on ways to involve the community in its activities.

Comparison value (CV)
Calculated concentration of a substance in air, water, food, or soil that is unlikely to cause harmful (adverse) health effects in exposed people. The CV is used as a screening level during the public health assessment process. Substances found in amounts greater than their CVs might be selected for further evaluation in the public health assessment process.

Completed exposure pathway [see exposure pathway].

Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA)
CERCLA, also known as Superfund, is the federal law that concerns the removal or cleanup of hazardous substances in the environment and at hazardous waste sites. ATSDR, which was created by CERCLA, is responsible for assessing health issues and supporting public health activities related to hazardous waste sites or other environmental releases of hazardous substances. This law was later amended by the Superfund Amendments and Reauthorization Act (SARA).

Concentration

The amount of a substance present in a certain amount of soil, water, air, food, blood, hair, urine, breath, or any other media.

Contaminant

A substance that is either present in an environment where it does not belong or is present at levels that might cause harmful (adverse) health effects.

Delayed health effect

A disease or an injury that happens as a result of exposures that might have occurred in the past.

Dermal

Referring to the skin. For example, dermal absorption means passing through the skin.

Dermal contact

Contact with (touching) the skin [see route of exposure].

Descriptive epidemiology

The study of the amount and distribution of a disease in a specified population by person, place, and time.

Detection limit

The lowest concentration of a chemical that can reliably be distinguished from a zero concentration.

Disease prevention

Measures used to prevent a disease or reduce its severity.

Disease registry

A system of ongoing registration of all cases of a particular disease or health condition in a defined population.

DOD

United States Department of Defense.

DOE

United States Department of Energy.

Dose (for chemicals that are not radioactive)

The amount of a substance to which a person is exposed over some time period. Dose is a measurement of exposure. Dose is often expressed as milligram (amount) per kilogram (a measure of body weight) per day (a measure of time) when people eat or drink contaminated water, food, or soil. In general, the greater the dose, the greater the likelihood of an effect. An "exposure dose" is how much of a substance is encountered in the environment. An "absorbed dose" is the amount of a substance that actually got into the body through the eyes, skin, stomach, intestines, or lungs.

Dose (for radioactive chemicals)

The radiation dose is the amount of energy from radiation that is actually absorbed by the body. This is not the same as measurements of the amount of radiation in the environment.

Dose-response relationship

The relationship between the amount of exposure [dose] to a substance and the resulting changes in body function or health (response).

Environmental media
Soil, water, air, biota (plants and animals), or any other parts of the environment that can contain contaminants.

Environmental media and transport mechanism
Environmental media include water, air, soil, and biota (plants and animals). Transport mechanisms move contaminants from the source to points where human exposure can occur. The environmental media and transport mechanism is the second part of an exposure pathway.

EPA United States Environmental Protection Agency.

Epidemiologic surveillance
[see Public health surveillance].

Epidemiology
The study of the distribution and determinants of disease or health status in a population; the study of the occurrence and causes of health effects in humans.

Exposure
Contact with a substance by swallowing, breathing, or touching the skin or eyes. Exposure may be short-term [acute exposure], of intermediate duration, or long-term [chronic exposure].

Exposure assessment
The process of finding out how people come into contact with a hazardous substance, how often and for how long they are in contact with the substance, and how much of the substance they are in contact with.

Exposure-dose reconstruction
A method of estimating the amount of people's past exposure to hazardous substances. Computer and approximation methods are used when past information is limited, not available, or missing.

Exposure investigation
The collection and analysis of site-specific information and biologic tests (when appropriate) to determine whether people have been exposed to hazardous substances.

Exposure pathway
The route a substance takes from its source (where it began) to its end point (where it ends), and how people can come into contact with (or get exposed to) it. An exposure pathway has five parts: a source of contamination (such as an abandoned business); an environmental media and transport mechanism (such as movement through groundwater); a point of exposure (such as a private well); a route of exposure (eating, drinking, breathing, or touching), and a receptor population (people potentially or actually exposed). When all five parts are present, the exposure pathway is termed a completed exposure pathway.

Exposure registry
A system of ongoing followup of people who have had documented environmental exposures.

Feasibility study
A study by EPA to determine the best way to clean up environmental contamination. A number of factors are considered, including health risk, costs, and what methods will work well.

Grand rounds

Geographic information system (GIS)

A mapping system that uses computers to collect, store, manipulate, analyze, and display data. For example, GIS can show the concentration of a contaminant within a community in relation to points of reference such as streets and homes.

Training sessions for physicians and other health care providers about health topics.

Groundwater

Water beneath the earth's surface in the spaces between soil particles and between rock surfaces [compare with surface water].

Half-life (t½)

The time it takes for half the original amount of a substance to disappear. In the environment, the half-life is the time it takes for half the original amount of a substance to disappear when it is changed to another chemical by bacteria, fungi, sunlight, or other chemical processes. In the human body, the half-life is the time it takes for half the original amount of the substance to disappear, either by being changed to another substance or by leaving the body. In the case of radioactive material, the half life is the amount of time necessary for one half the initial number of radioactive atoms to change or transform into another atom (that is normally not radioactive). After two half lives, 25% of the original number of radioactive atoms remain.

Hazard

A source of potential harm from past, current, or future exposures.

Hazardous Substance Release and Health Effects Database (HazDat)

The scientific and administrative database system developed by ATSDR to manage data collection, retrieval, and analysis of site-specific information on hazardous substances, community health concerns, and public health activities.

Hazardous waste

Potentially harmful substances that have been released or discarded into the environment.

Health consultation

A review of available information or collection of new data to respond to a specific health question or request for information about a potential environmental hazard. Health consultations are focused on a specific exposure issue. Health consultations are therefore more limited than a public health assessment, which reviews the exposure potential of each pathway and chemical [compare with public health assessment].

Health education

Programs designed with a community to help it know about health risks and how to reduce these risks.

Health investigation

The collection and evaluation of information about the health of community residents. This information is used to describe or count the occurrence of a disease, symptom, or clinical measure and to evaluate the possible association between the occurrence and exposure to hazardous substances.

Health promotion
The process of enabling people to increase control over, and to improve, their health.

Health statistics review
The analysis of existing health information (i.e., from death certificates, birth defects registries, and cancer registries) to determine if there is excess disease in a specific population, geographic area, and time period. A health statistics review is a descriptive epidemiologic study.

Indeterminate public health hazard
The category used in ATSDR's public health assessment documents when a professional judgment about the level of health hazard cannot be made because information critical to such a decision is lacking.

Incidence
The number of new cases of disease in a defined population over a specific time period [contrast with prevalence].

Ingestion
The act of swallowing something through eating, drinking, or mouthing objects. A hazardous substance can enter the body this way [see route of exposure].

Inhalation
The act of breathing. A hazardous substance can enter the body this way [see route of exposure].

Intermediate duration exposure
Contact with a substance that occurs for more than 14 days and less than a year [compare with acute exposure and chronic exposure].

In vitro
In an artificial environment outside a living organism or body. For example, some toxicity testing is done on cell cultures or slices of tissue grown in the laboratory, rather than on a living animal [compare with in vivo].

In vivo
Within a living organism or body. For example, some toxicity testing is done on whole animals, such as rats or mice [compare with in vitro].

Lowest-observed-adverse-effect level (LOAEL)
The lowest tested dose of a substance that has been reported to cause harmful (adverse) health effects in people or animals.

Medical monitoring
A set of medical tests and physical exams specifically designed to evaluate whether an individual's exposure could negatively affect that person's health.

Metabolism
The conversion or breakdown of a substance from one form to another by a living organism.

Metabolite
Any product of metabolism.

mg/kg
Milligram per kilogram.

mg/cm2
Milligram per square centimeter (of a surface).

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mg/m3

Milligram per cubic meter; a measure of the concentration of a chemical in a known volume (a cubic meter) of air, soil, or water.

Migration

Moving from one location to another.

An ATSDR estimate of daily human exposure to a hazardous substance at or below which that substance is unlikely to pose a measurable risk of harmful (adverse), noncancerous effects. MRLs are calculated for a route of exposure (inhalation or oral) over a specified time period (acute, intermediate, or chronic). MRLs should not be used as predictors of harmful (adverse) health effects [see reference dose].

Morbidity

State of being ill or diseased. Morbidity is the occurrence of a disease or condition that alters health and quality of life.

Mortality

Death. Usually the cause (a specific disease, a condition, or an injury) is stated.

Mutagen

A substance that causes mutations (genetic damage).

Mutation

A change (damage) to the DNA, genes, or chromosomes of living organisms.

National Priorities List for Uncontrolled Hazardous Waste Sites (National Priorities List or NPL)

EPA's list of the most serious uncontrolled or abandoned hazardous waste sites in the United States. The NPL is updated on a regular basis.

National Toxicology Program (NTP)

Part of the Department of Health and Human Services. NTP develops and carries out tests to predict whether a chemical will cause harm to humans.

No apparent public health hazard

A category used in ATSDR's public health assessments for sites where human exposure to contaminated media might be occurring, might have occurred in the past, or might occur in the future, but where the exposure is not expected to cause any harmful health effects.

No-observed-adverse-effect level (NOAEL)

The highest tested dose of a substance that has been reported to have no harmful (adverse) health effects on people or animals.

No public health hazard

A category used in ATSDR's public health assessment documents for sites where people have never and will never come into contact with harmful amounts of site-related substances.

NPL [see National Priorities List for Uncontrolled Hazardous Waste Sites]

Physiologically based pharmacokinetic model (PBPK model)

A computer model that describes what happens to a chemical in the body. This model describes how the chemical gets into the body, where it goes in the body, how it is changed by the body, and how it leaves the body.

Pica
A craving to eat nonfood items, such as dirt, paint chips, and clay. Some children exhibit pica-related behavior.

Plume
A volume of a substance that moves from its source to places farther away from the source. Plumes can be described by the volume of air or water they occupy and the direction they move. For example, a plume can be a column of smoke from a chimney or a substance moving with groundwater.

Point of exposure
The place where someone can come into contact with a substance present in the environment [see exposure pathway].

Population A group or number of people living within a specified area or sharing similar characteristics (such as occupation or age).

Potentially responsible party (PRP)
A company, government, or person legally responsible for cleaning up the pollution at a hazardous waste site under Superfund. There may be more than one PRP for a particular site.

ppb
Parts per billion.

ppm
Parts per million.

Prevalence
The number of existing disease cases in a defined population during a specific time period [contrast with incidence].

Prevalence survey
The measure of the current level of disease(s) or symptoms and exposures through a questionnaire that collects self-reported information from a defined population.

Prevention
Actions that reduce exposure or other risks, keep people from getting sick, or keep disease from getting worse.

Public availability session
An informal, drop-by meeting at which community members can meet one-on-one with ATSDR staff members to discuss health and site-related concerns.

Public comment period
An opportunity for the public to comment on agency findings or proposed activities contained in draft reports or documents. The public comment period is a limited time period during which comments will be accepted.

Public health action
A list of steps to protect public health.

Public health advisory
A statement made by ATSDR to EPA or a state regulatory agency that a release of hazardous substances poses an immediate threat to human health. The advisory includes recommended measures to reduce exposure and reduce the threat to human health.

Public health assessment (PHA)
An ATSDR document that examines hazardous substances, health outcomes, and community concerns at a hazardous waste site to determine whether people could be harmed from coming into contact with those substances. The PHA also lists actions that need to be taken to protect public health [compare with health consultation].

Public health hazard
A category used in ATSDR's public health assessments for sites that pose a public health hazard because of long-term exposures (greater than 1 year) to sufficiently high levels of hazardous substances or radionuclides that could result in harmful health effects.

Public health hazard categories
Public health hazard categories are statements about whether people could be harmed by conditions present at the site in the past, present, or future. One or more hazard categories might be appropriate for each site. The five public health hazard categories are no public health hazard, no apparent public health hazard, indeterminate public health hazard, public health hazard, and urgent public health hazard.

Public health statement
The first chapter of an ATSDR toxicological profile. The public health statement is a summary written in words that are easy to understand. The public health statement explains how people might be exposed to a specific substance and describes the known health effects of that substance.

Public health surveillance
The ongoing, systematic collection, analysis, and interpretation of health data. This activity also involves timely dissemination of the data and use for public health programs.

Public meeting
A public forum with community members for communication about a site.

Radioisotope
An unstable or radioactive isotope (form) of an element that can change into another element by giving off radiation.

Radionuclide
Any radioactive isotope (form) of any element.

RCRA [see Resource Conservation and Recovery Act (1976, 1984)]

Receptor population
People who could come into contact with hazardous substances [see exposure pathway].

Reference dose (RfD)
An EPA estimate, with uncertainty or safety factors built in, of the daily lifetime dose of a substance that is unlikely to cause harm in humans.

Registry
A systematic collection of information on persons exposed to a specific substance or having specific diseases [see exposure registry and disease registry].

Remedial investigation

The CERCLA process of determining the type and extent of hazardous material contamination at a site.

Resource Conservation and Recovery Act (1976, 1984) (RCRA)

This Act regulates management and disposal of hazardous wastes currently generated, treated, stored, disposed of, or distributed.

RFA

RCRA Facility Assessment. An assessment required by RCRA to identify potential and actual releases of hazardous chemicals.

RfD [see reference dose]

Risk

The probability that something will cause injury or harm.

Risk reduction

Actions that can decrease the likelihood that individuals, groups, or communities will experience disease or other health conditions.

Risk communication

The exchange of information to increase understanding of health risks.

Route of exposure

The way people come into contact with a hazardous substance. Three routes of exposure are breathing [inhalation], eating or drinking [ingestion], or contact with the skin [dermal contact].

Safety factor [see uncertainty factor]

SARA [see Superfund Amendments and Reauthorization Act]

Sample

A portion or piece of a whole. A selected subset of a population or subset of whatever is being studied. For example, in a study of people the sample is a number of people chosen from a larger population [see population]. An environmental sample (for example, a small amount of soil or water) might be collected to measure contamination in the environment at a specific location.

Sample size

The number of units chosen from a population or an environment.

Solvent

A liquid capable of dissolving or dispersing another substance (for example, acetone or mineral spirits).

Source of contamination

The place where a hazardous substance comes from, such as a landfill, waste pond, incinerator, storage tank, or drum. A source of contamination is the first part of an exposure pathway.

Special populations

People who might be more sensitive or susceptible to exposure to hazardous substances because of factors such as age, occupation, sex, or behaviors (for example, cigarette smoking). Children, pregnant women, and older people are often considered special populations.

Stakeholder

A person, group, or community who has an interest in activities at a hazardous waste site.

Statistics

A branch of mathematics that deals with collecting, reviewing, summarizing, and interpreting data or information. Statistics are used to determine whether differences between study groups are meaningful.

Substance

A chemical.

Substance-specific applied research

A program of research designed to fill important data needs for specific hazardous substances identified in ATSDR's toxicological profiles. Filling these data needs would allow more accurate assessment of human risks from specific substances contaminating the environment. This research might include human studies or laboratory experiments to determine health effects resulting from exposure to a given hazardous substance.

Superfund [see Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and Superfund Amendments and Reauthorization Act (SARA)

Superfund Amendments and Reauthorization Act (SARA)

In 1986, SARA amended the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and expanded the health-related responsibilities of ATSDR. CERCLA and SARA direct ATSDR to look into the health effects from substance exposures at hazardous waste sites and to perform activities including health education, health studies, surveillance, health consultations, and toxicological profiles.

Surface water Water on the surface of the earth, such as in lakes, rivers, streams, ponds, and springs [compare with groundwater].

Surveillance [see public health surveillance]

Survey

A systematic collection of information or data. A survey can be conducted to collect information from a group of people or from the environment. Surveys of a group of people can be conducted by telephone, by mail, or in person. Some surveys are done by interviewing a group of people [see prevalence survey].

Synergistic effect

A biologic response to multiple substances where one substance worsens the effect of another substance. The combined effect of the substances acting together is greater than the sum of the effects of the substances acting by themselves [see additive effect and antagonistic effect].

Teratogen

A substance that causes defects in development between conception and birth. A teratogen is a substance that causes a structural or functional birth defect.

Toxic agent

Chemical or physical (for example, radiation, heat, cold, microwaves) agents that, under certain circumstances of exposure, can cause harmful effects to living organisms.

Toxicological profile
An ATSDR document that examines, summarizes, and interprets information about a hazardous substance to determine harmful levels of exposure and associated health effects. A toxicological profile also identifies significant gaps in knowledge on the substance and describes areas where further research is needed.

Toxicology
The study of the harmful effects of substances on humans or animals.

Tumor
An abnormal mass of tissue that results from excessive cell division that is uncontrolled and progressive. Tumors perform no useful body function. Tumors can be either benign (not cancer) or malignant (cancer).

Uncertainty factor
Mathematical adjustments for reasons of safety when knowledge is incomplete. For example, factors used in the calculation of doses that are not harmful (adverse) to people. These factors are applied to the lowest-observed-adverse-effect-level (LOAEL) or the no-observed-adverse-effect-level (NOAEL) to derive a minimal risk level (MRL). Uncertainty factors are used to account for variations in people's sensitivity, for differences between animals and humans, and for differences between a LOAEL and a NOAEL. Scientists use uncertainty factors when they have some, but not all, the information from animal or human studies to decide whether an exposure will cause harm to people [also sometimes called a safety factor].

Urgent public health hazard
A category used in ATSDR's public health assessments for sites where short-term exposures (less than 1 year) to hazardous substances or conditions could result in harmful health effects that require rapid intervention.

Volatile organic compounds (VOCs)
Organic compounds that evaporate readily into the air. VOCs include substances such as benzene, toluene, methylene chloride, and methyl chloroform.

Other glossaries and dictionaries:

Environmental Protection Agency (http://www.epa.gov/OCEPAterms/)

National Center for Environmental Health (CDC)
(http://www.cdc.gov/nceh/dls/report/glossary.htm)

National Library of Medicine (NIH) (http://www.nlm.nih.gov/medlineplus/mplusdictionary.html)

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Appendix B. Definition of Comparison Values

When evaluating environmental contamination data, ATSDR uses a screening process to identify the subset of contaminants at a particular site that warrant more detailed consideration. The approach used to identify contaminants of potential health concern is comparing measured or estimated environmental contamination levels to health-based comparison values. These comparison values are developed from the scientific literature on exposures and health effects. Because most comparison values have uncertainty factors incorporated into them, these values are generally considered to be health-protective: environmental contamination found at levels below health-based comparison values are generally considered to have health risks that are very low or minimal. In other words, health-based comparison values are generally (and intentionally) selected to be lower than the lowest environmental concentrations known or suspected to be associated with adverse health effects, even considering the uncertainty in the underlying toxicological or epidemiological data. However, the opposite is not true: contamination levels greater than comparison values are not necessarily harmful. Rather, contaminants found at levels about comparison values require a more detailed toxicologic evaluation, such as the ones presented in the Public Health Implications section of this health consultation.

For this document, ATSDR first consulted with its own list of health-based comparison values, which are typically updated quarterly. ATSDR's comparison values for air contamination are available for different health endpoints (cancer and non-cancer) and exposure durations (acute, intermediate, and chronic). Thus, when applying the screening process to a given chemical, multiple comparison values are often considered. For chemicals for which ATSDR has not yet published a comparison value, the authors of this health consultation considered other sources of similar data. These other sources included an EPA region that has a broader set of comparison values for air (largely due to the fact that some comparison values were derived using cross-route extrapolations from ingestion toxicity studies) and occupational health standards. Occupational standards are often less protective than environmental health standards; however, in this case, all of the estimated ambient air concentrations in ATSDR's modeling analysis (see Appendix E) were at least two orders of magnitude lower than the corresponding standards.

The remainder of this appendix defines the different types of health-based comparison values that ATSDR used in its chemical screening process (Table B-1) and then lists the specific comparison values that were used for the 14 contaminants considered in the modeling analysis (Table B-2). In general, a relatively complete set of comparison values were available for the contaminants that were evaluated. The fact that many contaminants do not have comparison values available for cancer endpoints means that either the contaminant is not believed to be a carcinogen or insufficient data are available to establish its carcinogenicity.

Table B-1. Types of Comparison Values Used in This Health Consultation

Abbreviation	Explanation of Comparison Value
CREG	Cancer Risk Evaluation Guide, a highly health-protective and theoretical value reported by ATSDR that is believed to cause no more than one excess cancer in a million people exposed over time.
MRL	Minimal Risk Level, an ATSDR-derived estimate of daily human exposure to a dose of a chemical that is likely to be without an appreciable risk of adverse non-cancerous effects over a specified duration of exposure. MRLs are not based on consideration of cancer effects. MRLs are intended to serve as a screening tool to help public health professionals decide what to look at more closely. Exposure to a level above the MRL does not mean that adverse health effects will occur.
PEL	Permissible Exposure Limit, an enforceable air concentration derived by the Occupational Safety and Health Administration designed to protect workers against the health effects of exposures to hazardous substances. PELs are based on an 8-hour time weighted average exposure.
RBC	Risk-Based Concentration, a contaminant concentration that is not expected to cause adverse health effects over long-term exposures. The RBCs used in this health consultation were all developed (and periodically updated) by an EPA regional office for non-cancer outcomes.
REL	Acute Reference Exposure Levels, ambient air concentrations at or below which no adverse health effects are anticipated for a specified exposure duration. The values used in this health consultation were published by the California Office of Environmental Health Hazard Assessment. The acute RELs are based on the most sensitive, relevant, adverse health effect reported in the medical and toxicological literature, and are designed to protect the most sensitive individuals in the population by the inclusion of margins of safety.
RfC	Reference Concentration, an ambient air concentration derived by EPA that people, including sensitive subpopulations, likely can be exposed to continuously over a lifetime without developing adverse non-cancer health effects. RfCs typically have uncertainty factors built into them to account for any perceived limitations in the data on which they are based.
STEL	Short Term Exposure Limit, a 15-minute time weighted average air concentration that, according to the Occupational Safety and Health Administration, workers should not be exposed to at any time during a workday.

Table B-2. Comparison Values Used in This Document (See Table B-1 for Definitions)

Chemical	Comparison Values Used in this Health Consultation
1,1,1-Trichloroethane (TCA)	Cancer: None Noncancer (intermediate): 4,000 μg/m^3 (MRL) Noncancer (acute): 10,000 μg/m^3 (MRL)
1,2-Dichlorobenzene	Cancer: None Noncancer (chronic): 150 μg/m^3 (RBC) Noncancer (acute): 301,000 μg/m^3 (STEL)
Ethylbenzene	Cancer: None Noncancer (chronic): 1,000 μg/m^3 (RfC) Noncancer (acute): 545,000 μg/m^3 (STEL)
Ethylene glycol	Cancer: None Noncancer (chronic): 7,300 μg/m^3 (RBC) Noncancer (acute): 1,000 μg/m^3 (MRL)
Formaldehyde	Cancer: 0.08 μg/m^3 (CREG) Noncancer (chronic): 10 μg/m^3 (MRL) Noncancer (acute): 50 μg/m^3 (MRL)
Freon 113	Cancer: None Noncancer (chronic): 31,000 μg/m^3 (RBC) Noncancer (acute): 9,580,000 μg/m^3 (STEL)
Methanol	Cancer: None Noncancer (chronic): 1,800 μg/m^3 (RBC) Noncancer (acute): 28,000 μg/m^3 (REL)
2-Methoxyethanol	Cancer: None Noncancer (chronic): 20 μg/m^3 (RfC) Noncancer (acute): None
Methylene chloride (MC)	Cancer: 3 μg/m^3 (CREG) Noncancer (chronic and intermediate): 1,000 μg/m^3 (MRL) Noncancer (acute): 2,000 μg/m^3 (MRL)
Methyl ethyl ketone	Cancer: None Noncancer (chronic): 5,000 μg/m^3 (RfC) Noncancer (acute): 13,000 μg/m^3 (REL)
Phenol	Cancer: None Noncancer (chronic): 1,100 μg/m^3 (RBC) Noncancer (acute): 5,800 μg/m^3 (REL)
tert-Butyl alcohol	Cancer: None Noncancer (chronic): 300,000 μg/m^3 (PEL) Noncancer (acute): 450,000 μg/m^3 (STEL)
Tetrachloroethylene (PCE)	Cancer: 2 μg/m^3 (former CREG, see note at end of table) Noncancer (chronic): 300 μg/m^3 (MRL) Noncancer (acute): 1,000 μg/m^3 (MRL)
Xylenes	Cancer: None Noncancer (chronic): 100 μg/m^3 (RfC) Noncancer (acute): 1,000 μg/m^3 (MRL)

Note: The "former CREG" listed for PCE is based on a cancer unit risk factor that EPA had previously reported for this chemical. EPA's unit risk factor for PCE is currently listed as being "under review." Though ATSDR no longer reports a CREG in its periodic release of comparison values, the former CREG was used for initial screening purposes. The Public Health Implications section of this health consultation considers the broader scientific literature on PCE's carcinogenic potential.

Appendix C. Review of Air Emissions Data

The IBM facility emitted many different chemicals into the air, and these emissions originated from numerous sources, including stacks and passive releases from tanks, flanges, valves, pump seals, and other fittings. Other industrial facilities in the Endicott area emitted many of the same pollutants into the air. This appendix presents ATSDR's review of the available emissions data, considering all facilities in the area and then focusing on the IBM facility.

C.1   Relative Amounts of Emissions From Industrial Facilities in the Endicott Area

When first addressing this site, ATSDR accessed air emissions data that industrial facilities throughout the Endicott area disclosed to EPA's Toxics Release Inventory (TRI). Queries of this database identified seven industrial facilities (including IBM) in the Endicott area that reported some air emissions to TRI during 1987–1993, the time frame of greatest interest for this health consultation. Refer to Figure 2 for the names and locations of these facilities. Upon comparing TRI data among these facilities, ATSDR noted that IBM's air emissions clearly accounted for the overwhelming majority of the area-wide air emissions from these industrial sources, particularly for the volatile chemicals of greatest interest to community members (see Table C-1). On the basis of this evaluation, ATSDR determined that it was appropriate for this health consultation to focus primarily on historic outdoor air emissions from the IBM facility, consistent with the community concerns, while acknowledging potential contributions from other sources to the extent appropriate.

ATSDR acknowledges that basing this judgment on TRI data has some limitations. For example, the review of TRI data does not account for air emissions from industrial facilities and commercial operations (e.g., dry cleaners) that did not meet the TRI reporting requirements. Additionally, emissions data in TRI are self-reported and may understate or overstate actual emissions. These limitations notwithstanding, TRI data are the best available information for gauging relative contributions to outdoor air emissions sources, and the data clearly show that air emissions from the former IBM facility accounted for a substantial portion of the total emissions from facilities in the Endicott area, thus justifying the decision to focus this health consultation on IBM's emissions.

C.2   Review of IBM's Emissions Data

Based on an understanding of the manufacturing processes and information documented in NYSDEC's files, ATSDR determined that environmental health issues associated with historic outdoor air emissions from the IBM Endicott are most logically addressed by considering the following distinct time frames:

- *Before 1987: Emission rates are not known.* ATSDR did not locate any quantitative emissions data for years preceding 1987, which is the first year that industrial facilities were required to comply with TRI reporting regulations. Although several files specify the quantities of chemicals that IBM used in certain years before 1987 (IBM, 2005a; 2005b), air emission rates cannot be calculated directly from the chemical usage data. Therefore, ATSDR has no basis for quantifying air emissions data from IBM for years preceding 1987, although qualitative judgments about emissions can be inferred from

chemical usage. Years preceding 1987 were broken up into additional time frames when commenting on the usages of specific chemicals of concern (e.g., see Tables 2 to 6).

- *1987–1993: Air emission rates are well documented, and IBM greatly reduces emission rates.* From 1987 through 1993, IBM went from being one of the nation's largest emitters of selected chlorinated solvents to nearly eliminating all uses of these chemicals. In 1987, the IBM Endicott facility reportedly emitted more ozone-depleting substances than any other facility in the United States (USA Today, 1989). A similar trend was observed in 1988, when the facility ranked among the nation's top 10 emitters of multiple chlorinated solvents, including methylene chloride, 1,1,1-trichloroethane, and freon 113. For reference, Table C-2 lists the air emissions data that IBM reported to TRI during 1987–1994 for the chemicals of greatest interest.

  One notable trend apparent from Table C-2 is the considerable reductions in air emission rates. Shortly after the original TRI emissions data were publicized, IBM, working in conjunction with the New York State Attorney General's Office and the New York State Department of Environmental Conservation (NYSDEC), developed a program to drastically reduce its air emissions and to eventually eliminate uses of ozone-depleting substances. As noted previously, IBM made numerous process changes from 1989 through 1993 as part of this pollution prevention program. These changes and other improvements were extremely effective: based on TRI data, the total facility-wide air toxics emissions in 1994 were only 3% of the facility-wide air toxics emissions in 1988. During this time frame, IBM reduced its air toxics emissions by more than 4,300,000 pounds. Information in NYSDEC's permitting files reflects the significant re-engineering that occurred at IBM during 1989–1993. These files note, for example, that many air emissions sources were modified multiple times during this time frame, while others were dismantled altogether.

  Overall, for purposes of this health consultation, the period 1987–1993 is unique for two reasons: it includes years when IBM used extremely large quantities of VOCs (unlike the time frame after 1993), and it has quantitative emissions data that can be used to support an air dispersion modeling analysis (unlike the years preceding 1987).

- *1994 to the present: Emission rates are relatively insignificant.* After IBM stopped using ozone-depleting substances, placed greater controls on fugitive emissions, and switched from solvent-based operations to many aqueous-based operations, the facility's air emissions decreased dramatically and remained at relatively low levels until IBM sold the property in 2002. In fact, for methylene chloride, 1,1,1-trichloroethane, and freon 113, IBM's usage after 1993 was below levels that would trigger TRI reporting for these chemicals. Therefore, facility-wide emission rates for years since 1994 are not available for many chemicals that IBM previously processed in large quantities. To a first approximation, the air quality impacts associated with these chemicals during 1994 through 2002 (i.e., the year IBM sold the property) were likely no higher than the modeling predictions for 1993 presented elsewhere in this health consultation.

Table C-1. Percent of Toxic Chemical Emissions From Selected Industrial Sources in the Endicott Area (see Figure 2) Attributed to the Former International Business Machines Corporation (IBM) Facility, 1988–1993

Year	Percent of Total Toxic Chemical Air Emissions Attributed to IBM	Contribution of IBM's Emissions to the Total Emissions for Toxic Chemicals Identified in Community Concerns			
		Freon 113	MC	PCE	TCA
1988	96.0%	97.7%	100.0%	100.0%	100.0%
1989	86.9%	98.8%	100.0%	100.0%	100.0%
1990	82.8%	96.4%	100.0%	100.0%	100.0%
1991	74.2%	95.0%	87.9%	100.0%	90.4%
1992	76.3%	100.0%	100.0%	100.0%	100.0%
1993	61.2%	100.0%	100.0%	100.0%	100.0%

Notes: The table is based on air emissions data reported to TRI for the industrial facilities shown in Figure 2 of this document. All emissions data were downloaded from EPA's TRI website (www.epa.gov/tri). Refer to earlier sections of this health consultation for a discussion of the limitations associated with using TRI data (see page 10).

The numbers in the second column were calculated as follows: total facility-wide TRI emissions data (i.e., summed across all toxic chemicals) from IBM were divided by the total TRI emissions data for all seven facilities shown in Figure 2 of this document.

The numbers in the third through sixth columns were calculated in a similar fashion. For the third column, for example, IBM's total facility-wide TRI emissions data for Freon 113 were divided by the total TRI emissions of Freon 113 reported by all seven facilities shown in Figure 2 of this document. Data in the fourth through sixth columns were then calculated accordingly, except using emissions data for the other three chemicals of interest.

Table C-2. Air Emissions From the Former International Business Machines Corporation (IBM) Facility, 1987–1994

Reporting Year	Total Annual Air Emissions (pounds), by Chemical			
	Freon 113	MC	TCA	PCE
1987	1,110,000	1,600,000	1,510,000	116,000
1988	1,028,000	1,927,000	1,144,000	148,000
1989	484,200	120,500	120,200	109,000
1990	296,000	94,000	113,000	90,000
1991	170,000	95,000	111,000	62,000
1992	150,800	89,500	74,000	45,300
1993	42,300	52,590	27,130	35,200
1994	Not reported	Not reported	14,800	27,120
Other VOCs that IBM emitted during 1987–1994 (based on TRI data): t-Butyl alcohol, 1,2-dichlorobenzene, 1,1-dichloro-1-fluoroethane, ethylbenzene, ethylene glycol, formaldehyde, methanol, 2-methoxyethanol, methyl ethyl ketone, phenol, xylenes.				

Notes: Source of data: TRI data downloaded from EPA's TRI website (for reporting years 1988–1994) and from EPA's Envirofacts website (for reporting year 1987).

MC = methylene chloride; TCA = 1,1,1-trichloroethane; PCE = tetrachloroethylene.

"Not reported" means that IBM did not submit emissions data for the given reporting year to TRI, which, in this case, means that the facility did not use more than 10,000 pounds of the listed chemical in the given reporting year.

Appendix D. Review of Air Dispersion Modeling Studies

This appendix presents ATSDR's review of four different modeling studies that were accessed from site records. ATSDR thoroughly reviewed each of these studies before determining whether conducting another modeling study was necessary. Note that the conclusions of this health consultation are based entirely on ATSDR's 2005 modeling analysis (see Appendix E) and not on the studies documented below. The information presented in this appendix is intended for readers who seek technical details on other modeling studies of IBM's historic outdoor air emissions.

D.1 Review of IBM's "Phase 1" Modeling Analysis (ENSR Consulting and Engineering, 1988)

In 1988, consultants to IBM conducted a dispersion modeling analysis that estimated the facility's air quality impacts of four chlorinated solvents: Freon 113, MC, PCE, TCA. Models were run using air emissions data almost identical to those that IBM reported to TRI in 1987 and focused on the chemicals that IBM previously emitted in greatest quantities. According to the report, the overwhelming majority of air emissions for these chemicals originated in Buildings 18, 41, and 47. These buildings are located near where McKinley Avenue passes through the IBM facility. Fugitive emissions were modeled as passive releases (i.e., no exit velocity), and the fugitive emissions for a given building were apportioned equally between hypothetical stack sources on the rooftops.

IBM's consultants used two dispersion models in their analysis. The Industrial Source Complex – Long Term (ISCLT) model was used to evaluate air quality impacts in simple terrain, and the VALLEY model was used to simulate dispersion in complex terrain. Both models were suitable selections at the time, but more recent computer codes and newer generation models are now available. Of the two models used, greater air quality impacts were observed with the ISCLT simulations, presumably due to building downwash effects (which the VALLEY model does not simulate). Model simulations were run for receptors within 1,500 meters of the facility boundary, where air quality impacts were expected to be greatest. A table in the dispersion modeling report lists all source parameters used as model inputs (e.g., stack coordinates, stack heights, stack diameters, exit flow rates, building dimensions). Meteorologic data for these simulations were reportedly taken from observations made at Broome County Airport in 1982, 1985, and 1987. No reason was provided for why other years of data were not considered.

The modeling report presented estimates of the highest off-site annual average concentrations associated with the IBM facility's 1987 emission rates. For all chemicals, fugitive emissions accounted for between 85% and 99% of the maximum concentrations. The highest off-site concentrations were observed for locations within 350 meters from the facility boundary, but the report does not clearly state where these locations are. The report noted that the estimated concentrations all complied with New York State's "Acceptable Ambient Levels" (AALs) at the time.

ATSDR identified two notable limitations with the Phase 1 modeling. First, the modeling does not consider short-term air quality impacts—an issue that currently is routinely considered when characterizing air quality impacts from industrial facilities. Second, the modeling analysis was

run using 3 non-consecutive years of meteorologic data. While standard modeling practice typically calls for using 5 consecutive years, when possible, such a complete data set apparently was not available at the time the Phase 1 modeling study was completed. These limitations aside, the Phase 1 modeling appears to be based largely on sound scientific principles.

D.2   IBM's "Phase 2" modeling analysis (ENSR Consulting and Engineering, 1989)

In March 1989, consultants to IBM conducted an updated modeling analysis. The modeling was reportedly conducted to "form part of an air toxics risk assessment for the facility." The primary difference between the Phase 1 and Phase 2 modeling is the emission rate inputs. In Phase 2, the models were run using emissions "data generated by IBM from operating permits and a source sampling study conducted during the fall of 1988." However, the report presents no further information on the emissions data. ATSDR determined that the emission rates for three of the four chemicals fall between levels that IBM reported in its 1988 and 1989 TRI submissions. Outside of the differences in emission rate inputs, virtually all other modeling inputs and assumptions in Phase 2 were identical to those used in Phase 1. Therefore, the same limitations identified for the Phase 1 modeling also apply here.

For all four chemicals considered, the Phase 2 modeling analysis estimated maximum offsite air quality impacts lower than those predicted in the Phase 1 study. These lower estimated concentrations are roughly proportional to the reduced chemical-specific emission rates used as model inputs for Phase 2 (and consistent with the gradual decrease in facility-wide emission rates that began to occur in the late 1980s).

D.3   IBM's "Phase 3" modeling analysis (ENSR Consulting and Engineering, 1991)

In 1991, IBM's consultants completed a third round of air dispersion modeling. There are two notable differences between this final modeling analysis and the Phase 1 and Phase 2 studies. First, the emission rates in the Phase 3 work are considerably lower than those used previously, especially for MC and TCA, and reflect the substantial reduction in fugitive emissions that occurred at the former IBM facility. Second, the Phase 3 modeling apportioned the emissions to individual sources in a much different fashion than was done previously. In Phase 1 and Phase 2, fugitive emissions accounted for between 65% and 90% of the total emissions for the four chemicals modeled. In Phase 3, on the other hand, fugitive emissions accounted for only 1% of the total emissions for three of the four chemicals. The lower proportion of fugitive emissions in the Phase 3 modeling analysis is consistent with many emissions reduction measures that IBM implemented, such as substituting chlorinated solvents with non-volatile aqueous solutions and encasement of all outside piping and enclosure of storage tanks and loading docks to prevent leaks and spills.

For all four chemicals considered, the Phase 3 modeling analysis predicted air quality impacts considerably lower than those predicted in either the Phase 1 or Phase 2 studies. These lower estimates result from both the lower emission rates considered and the approach to apportioning these emissions between fugitive and stack sources.

D.4   NYSDOH's modeling analysis (NYSDOH, 1996)

In 1996, NYSDOH released a health consultation that evaluated the public health implications of air emissions data reported by industrial facilities within 2.5 miles of the boundary of the Endicott municipal water supply service area. Using an air dispersion modeling analysis, NYSDOH concluded that the air emissions reported by these facilities—including the IBM Endicott facility—are not sources of significant increased health risks. Accordingly, NYSDOH recommended no further evaluation of air emissions data. This evaluation was based entirely on TRI data that industrial facilities submitted for reporting year 1988.

When estimating air quality impacts, NYSDOH used the SCREEN dispersion model, which has been widely used for this purpose. NYSDOH made three key assumptions when running the model. First, it was assumed that all air emissions from each facility originated from a single source at the facility center. While some assumption had to be made regarding the spatial allocation of emissions, placing all emissions at the point furthest from the property line does not adequately represent conditions at IBM, where some buildings and emissions sources are located in close proximity to the property line. Second, and more importantly, the SCREEN model was run for a single set of meteorologic conditions: neutral atmospheric stability, with wind speeds of 5 meters per second. This assumption was made because these were reportedly the most common meteorologic conditions in the state of New York. While the meteorologic conditions selected may indeed have occurred most frequently, highly stable conditions often contribute to the greatest air quality impacts, even though these conditions may not be observed frequently. Third, the nearest receptor considered in this evaluation was 500 meters (or 0.3 miles) from the source. However, many residents lived much closer to the facility, and use of this receptor distance caused the modeling to not consider building downwash effects, which can lead to considerably higher concentration estimates.

For these reasons, ATSDR believes that NYSDOH's modeling analysis likely understated IBM's actual air quality impacts. As evidence of this, ambient air concentrations predicted by NYSDOH were more than 10 times lower than those predicted in IBM's Phase 1 modeling, even though the emission rates used in these studies were comparable. However, it should be noted that NYSDOH's analysis was conducted as part of the 1996 Public Health Assessment for the Endicott Village Wellfield, and was not intended specifically to characterize IBM's air quality impacts. Rather, NYSDOH conducted its modeling to screen emissions reported to TRI from various industrial facilities and to evaluate the health significance of other potential sources of exposure in addition to the wellfield.

D.5   Summary

The four available modeling studies predicted air quality impacts that span more than an order of magnitude. The differences in estimated concentrations largely result from the differences in emission rates used as model inputs; however, ATSDR also found that the approach taken to apportion emissions between individual sources also accounts for some of the variability in the modeling outputs. Overall, IBM's past modeling studies provide the most realistic accounts of past air quality impacts, because these studies attempted to represent emissions from individual stacks and considered site-specific meteorologic data. However, ATSDR also proceeded with a new modeling study for the following reasons: a new study could incorporate the most recent

ISC dispersion and downwash algorithms; a new study could consider a more complete set of meteorologic data; a new study could provide rough estimates of potential short-term air quality impacts; a new study could provide a "reality check" on the previous studies, for which input and output files are not available to verify their accuracy; and a new study could offer a fully documented account of all inputs, assumptions, limitations, and uncertainties associated with the modeling predictions. Appendix E documents the updated study that ATSDR conducted to account for and address the limitations of the past evaluations.

Appendix E. ATSDR's 2005 Dispersion Modeling Study

After deciding to conduct its own dispersion modeling study, ATSDR first developed a draft dispersion modeling protocol (ERG 2005), which was reviewed by multiple agency partners. Main points from the modeling protocol are presented here. A complete copy of the protocol and electronic files of modeling inputs are available upon request. The modeling results were then documented in a draft report summarized here (ERG 2006).

The objective of the modeling analysis was to estimate the magnitude and spatial distribution of ambient air concentrations (for both acute and chronic exposure durations) of 14 chemicals that IBM emitted into the air during 1987–1993. The modeling protocol explains why the analyses were limited to these years and these chemicals. All modeling was conducted with the Industrial Source Complex, Short Term (ISC3) model. At the time this project was initiated, this was the model that EPA recommended for evaluating multiple sources in areas with simple terrain, much like the conditions nearest the former IBM facility in Endicott. The modeling protocol identifies the facility-wide emission rates that were used for the modeling, along with the approach used to apportion those emissions among individual stack and fugitive sources.

As the protocol explains, atmospheric dispersion was modeled over a spatial domain that extends up to 5 miles in all compass directions from the IBM facility. Following standard dispersion modeling approaches, a fine grid of receptors (100-meter spacing) was used nearest the facility, and a coarse grid of receptors (250-meter spacing) was used at further distances. Modeling was conducted using surface meteorologic data collected during 1987–1993 at the Binghamton Airport (Surface Station #04725) and upper air data for the same years from a National Weather Service station located in Albany, New York. Consideration was given to using several other sources of meteorologic data, particularly for surface winds, but none were judged to be complete enough to support dispersion modeling. It should be noted that IBM's Phase 1-3 modeling projects and a more recent study conducted for IBM (O'Brien and Gere Engineers, 2005) that ATSDR identified for the Endicott area (many of which were reviewed and approved by NYSDEC) also used this same combination of meteorologic data sets. Emissions were apportioned among 42 stacks (or "point" sources) and 19 fugitive emissions sources, which were modeled as hypothetical passive vent stacks. Building downwash and standard regulatory default options were used in the modeling analyses.

The remainder of this appendix documents various finer technical details of the modeling analyses:

E.1 Source Characterization: Emissions Data

The following paragraphs describe ATSDR's proposed approach for characterizing facility-wide emission rates, building-to-building variations in emissions, and year-to-year variations in emissions. For each topic, comments are provided on the perceived quality of emissions data.

- **Facility-wide Emission Rates Used in Modeling.** ATSDR's modeling was based on the facility-wide emission rates that IBM reported to TRI. An important issue considered when conducting the modeling was the quality of the emissions data, given that inaccuracies in the emissions will translate directly into inaccuracies in

the estimated ambient air concentrations. A standard concern with using TRI data is that emission rates are self-reported and the quality of an individual facility's submissions is not known. However, all facilities are required to certify their TRI submissions as being "accurate based on reasonable estimates" of the best available information. Further, the TRI program provides facilities the opportunity to revise or withdraw data that are later found to be erroneous, but IBM apparently did not do so. Additionally, the TRI emissions data considered in this modeling are all for volatile chemicals that IBM "otherwise used" and that generally did not enter the facility's products. For such scenarios, the amounts of chemicals taken from inventory in a given year (which can be readily quantified using purchasing data or inventory reconciliation) are typically balanced primarily by air emissions and quantities managed as wastes. Thus, if the amounts of chemicals taken from inventory and the quantities managed as wastes are known, then the total facility-wide air emissions can be estimated to a reasonable degree of accuracy.

ATSDR acknowledges that none of the previous observations confirms that the emissions data proposed for modeling are accurate. However, several other data sources identified in NYSDEC's files paint a fairly consistent picture of the quantities of VOCs that IBM emitted. For instance, the following data sources all present information on facility-wide stack emissions comparable to the TRI data:

o   Emission rates that IBM's consultants entered into three different modeling studies (ENSR Consulting and Engineering 1988, 1989a, 1991) all fell within the ranges of emissions data that IBM reported to TRI in the corresponding years.

o   A 1990 "Summary of IBM Endicott Emissions" that was found in NYSDEC's files quotes facility-wide stack emission rates that all fall within the range of the TRI data that IBM submitted between 1988 and 1990 (Krush 1990).

o   A "1990 Industrial Process Emissions Survey" prepared by IBM reports facility-wide stack emissions data that are identical (except reported to different significant figures) to the TRI emissions data for the same year (IBM 1992). It should be noted that an IBM official certified that the emissions data in the survey "represents the best available data and is true and accurate to the best of my knowledge and ability."

o   As recently as 1994, IBM submitted documents to NYSDEC that reported 1987 emissions levels for certain chemicals identical to those reported to TRI.

o   ATSDR tabulated "actual emissions" data that appeared on certificates to operate during 1987–1993. The facility-wide stack emissions computed from the COs for all four chemicals are generally similar to the data trends in the TRI data.

Taken together, the observations throughout this section suggest that, during 1987–1993, IBM and its consultants published numerous reports, memos, and other documents that

provide a reasonably consistent account of the facility-wide annual air emission rates for the four VOCs emitted in greatest quantities. The consistency across the multiple documents provides some assurance that the proposed inputs (i.e., the TRI emissions data) are appropriate for this analysis, though ATSDR acknowledges that the actual emission rates are not known (as is typically the case for facilities with large amounts of fugitive emissions sources). The magnitude of uncertainty in the emission rates cannot be quantified.

- **Spatial allocation of stack emissions (1987).** The former IBM facility housed numerous production operations located in multiple buildings. A rigorous dispersion modeling analysis must account for the spatial allocation of emissions among these buildings, as failure to do so would undoubtedly introduce bias into the model predictions, particularly for receptors closest to the facility. ATSDR allocated emissions among major production buildings and individual sources based on emissions data that were reported in three previous modeling studies (ENSR Consulting and Engineering 1988, 1989a, 1991) and in the facility's certificates to operate. A detailed account of this approach to allocating stack emissions to individual sources is documented in the draft dispersion modeling protocol (ERG 2005). Sensitivity analyses were conducted to determine whether assumptions made in allocating stack emissions to individual sources had significant impacts on the modeling results, as described later in this appendix.

- **Spatial allocation of fugitive emissions (1987).** Of all the data sources reviewed, only one—IBM's three modeling studies—presents information on the estimated distribution of fugitive emissions among the former production buildings. This same distribution was applied in ATSDR's dispersion modeling. ATSDR examined multiple data sources to determine whether the available information is internally consistent. The one notable observation was that the spatial allocation of stack emissions and that proposed for fugitive emissions were generally similar (i.e., buildings with the highest stack emissions also tended to have the highest fugitive emissions for specific VOCs). These similarities by no means should be viewed as "validating" the proposed distribution of fugitive emissions, but they do not reveal any gross inconsistencies.

- **Temporal allocation of emissions.** The previous paragraphs describe how ATSDR computed emission rates for individual sources for 1987. However, additional information was needed to characterize how emission rates changed at each stack from year to year, especially considering that site reports quite clearly indicate that IBM's air emissions decreased dramatically during 1987–1993. Unfortunately, data documenting source-specific changes in emissions are not available. Without this source-specific data, ATSDR assumed that the net increases or decreases in stack or fugitive emissions between one year and the next were equally distributed amongst the stack and fugitive sources. The proposed approach of evenly distributing emissions reductions across all sources introduces uncertainty into the modeling analysis. Sensitivity analyses, as described later in this appendix, were used to attempt to quantify the magnitude of uncertainty associated with this proposed approach.

ATSDR's modeling also evaluated short-term air quality impacts. This evaluation considered only the extent to which fluctuations in meteorology might have affected ambient air concentrations, because no detailed information on temporal changes in emissions data was available. More specifically, the modeling could not address fluctuations in emissions because none of the site records provided such data. Thus, the modeling analysis assumed that the annual emissions totals submitted to TRI occurred evenly throughout the year. This approach likely understates the peak emission rates that likely occurred during process upsets, leaks, spills, and other episodic events, but no scientifically valid approach is available to provide better characterization of the short-term emissions. Therefore, the model outputs for short-term air quality impacts are expected to have considerable (but unquantifiable) uncertainty that likely understates IBM's air quality impacts.

E.2   Model Selection and Inputs

The specific model input parameters that ATSDR used were taken from multiple data sources. For instance, the proposed stack parameters come from air permitting data that NYSDEC has on file; the proposed emission rates come from IBM's self-reported TRI data; and additional insights are taken from the modeling studies previously conducted by IBM's consultants. The remainder of this section describes important decisions about model selection and model inputs.

ATSDR used the Industrial Source Complex, Short Term (ISCST3) model to evaluate air quality impacts from the IBM Endicott facility. At the time this project began, EPA recommended use of ISCST3 for modeling continuous releases of air contaminants from multiple sources in areas with simple terrain, much like the conditions in Endicott.[5] Following are some general inputs for the dispersion modeling analysis:

- **Temporal resolution.** ATSDR ran separate modeling simulations for each of the calendar years of interest (1987, 1988, 1989, 1990, 1991, 1992, and 1993). In each simulation, the model estimated the following concentrations at every receptor defined below: maximum 1-hour average concentration, maximum 24-hour average concentration, and annual average concentration. As noted previously, because information on short-term peaks in emissions data is not available, the estimated 1-hour and 24-hour average concentrations strictly reflect temporal variations in local meteorologic conditions. Ideally, information on day-to-day or even hour-to-hour changes in emission rates would also be considered in this modeling. However, this variability is not characterized in any of the site documents and therefore cannot be addressed.

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[5] IBM's previous modeling analyses considered the potential for elevated air quality impacts in areas with complex terrain, given that the local terrain gradually rises to the north and the west of the facility. However, that modeling found that the fugitive emissions contributed most to air quality impacts, which were greatest near the facility. At the more distant receptors in complex terrain, concentration estimates using the complex terrain modeling algorithms were generally consistent with the simple terrain estimates from ISC. Thus, complex terrain was not explicitly modeled by ATSDR.

- **Spatial domain (receptor locations).** Atmospheric dispersion was modeled over a spatial domain that extends up to 5 miles in all compass directions from the IBM facility. This spatial domain was considered sufficient, given that the past modeling studies all suggest that the highest air quality impacts were nearest the facility. Concentrations were estimated at hundreds of different points, typically referred to as "receptors." More specifically, the modeling considered fence-line receptors, which were evenly spaced (at 25-meter intervals) around the facility perimeter. The modeling also considered two different modeling grids to characterize past air quality impacts in the community. In the immediate vicinity of the facility, receptors were placed on a fine grid, with 50-meter spacing. Further from the facility, a coarse grid was used with 150-meter spacing. Given that the focus of this evaluation is on environmental exposures and not occupational exposures, air quality impacts were not estimated for locations within the facility boundary.

- **Meteorologic data.** For surface data, previous modeling analyses of IBM Endicott's air emissions considered 3 years of observations from the Binghamton Airport, which is located approximately 7 miles northeast of the facility. The airport is located in the valley of a tributary to the Susquehanna River, but the orientation of the valley in which the airport lies differs from the east-west orientation of the Susquehanna River valley where the IBM facility is located. ATSDR conducted a thorough review of alternate sources of surface data (e.g., the Tri-Cities Airport), but none of these sources were found to have complete enough data to support dispersion modeling. Accordingly, the modeling was based entirely on surface data from Binghamton Airport and upper air data from Albany Airport. The data that were used were collected during 1987–1993.

- **Source characteristics for stack emissions.** ATSDR's modeling considered 34 different stack emission points. Table E-1 lists the stack parameters—height, diameter, velocity, and temperature—that ATSDR used in its dispersion modeling analysis. These parameters were entered directly into the model input files and were selected as follows: First, for any stack that was previously considered in IBM's modeling analyses, the parameters documented in those modeling reports are proposed for this application. Second, for stacks not considered previously by IBM, stack parameters from the certificates to operate (air permits) were used. In cases where the certificates to operate suggested stack parameters changed over the time frame of interest (1987–1993), the stack parameters cited most frequently were proposed for this application.

- **Source characteristics for fugitive emissions.** The only information ATSDR located regarding fugitive emissions source characteristics is from IBM's former modeling studies. These studies split fugitive emissions among several 1-meter diameter hypothetical stacks that were evenly spaced along the top of the corresponding processing buildings. Emissions were modeled as passive releases at ambient temperature, with an exit velocity of 0.001 meters/second. Given that fugitive emissions are expected to account for the majority of air quality impacts, at least for the near field receptors, ATSDR conducted sensitivity analyses to determine how the predicted concentrations vary with other approaches for representing fugitive emissions, as described later in this appendix.

- **Other modeling options.** For model run-time options, ATSDR used standard regulatory default modeling options, as appropriate. The modeling analysis considered building downwash (using the same building dimensions that were programmed into past modeling analyses), stack-tip downwash, and rural dispersion coefficients. The modeling did not account for any degradation or deposition mechanisms.

E.3   Modeling Results

ATSDR's modeling analysis estimated ambient air concentrations for 14 chemicals. Of these, estimated concentrations for 3 chemicals (formaldehyde, methylene chloride, and tetrachloroethylene) exceeded health-based comparison values and were evaluated in detail in the main body of this health consultation. For the remaining 11 chemicals, estimated ambient air concentrations were below health-based comparison values and therefore were not considered further in ATSDR's analysis of health effects attributed to single chemicals, though the possibility of health effects associated with exposures to chemical mixtures was considered. For reference, Table E-2 lists the estimated ambient air concentrations for the 11 chemicals that were found to have air quality impacts below their corresponding health-based comparison values (see Appendix B).

E.4   Uncertainties and Limitations

Uncertainty in dispersion modeling evaluations comes from various sources. For instance, the ISC3 model, though periodically updated to reflect the current state of the science, does not perfectly represent the many and varied fate and transport mechanisms that affect atmospheric dispersion. Therefore, even if the model inputs for this facility were perfectly characterized, the estimated concentrations would likely either overstate or understate actual air quality impacts. The dispersion modeling predictions do tend to be most accurate for estimating long-term (e.g., annual average) ambient air concentrations, with the predictive ability of most models decreasing with shorter averaging periods. For short-term impacts, air dispersion models can adequately predict the magnitude of peak concentrations when inputs are appropriately characterized, but the models tend to perform less well in predicting exactly when and where the highest short-term concentrations would have occurred.

Some types of uncertainty in ATSDR's modeling cannot be quantified, such as the inherent uncertainty associated with the ISC3 dispersion algorithms and the uncertainty associated with use of meteorologic data from the Binghamton Airport. However, an opportunity existed to use sensitivity analyses to evaluate the magnitude of uncertainty introduced by certain modeling assumptions and model input parameters. Following is a summary of the sensitivity analyses that were conducted:

- **Impact of assumptions made in spatial allocation of emissions.** ATSDR made several assumptions when allocating stack emissions to individual point sources when conducting the modeling. One assumption distributed emissions for certain small point sources that could not be easily modeled (due to increased run time if the smallest releases were modeled separately) equally among other sources. This assumption was made to facilitate the modeling analyses by limiting the number of sources to address (but

without decreasing the emissions); however, some uncertainty was introduced by allocating emissions from the small number of sources to other stacks. ATSDR investigated the impact of this assumption with a sensitivity analysis on one of the chemicals. At the point of maximum impact, the sensitivity analysis simulation found that the approach taken to reallocate emissions from the least significant stack sources had virtually no impact on the estimated air quality impacts.

- **Impact of inputs selected to model fugitive emissions as hypothetical stacks.** As noted previously, ATSDR's modeling analysis represented fugitive emissions as point sources equally spaced atop the buildings from which the emissions originated. Based on review of past modeling studies for the IBM facility, these hypothetical stacks were assigned diameters of 1.0 meters and exit velocities of 0.001 meters per second. The sensitivity analyses for the fugitive emissions considered the following three possibilities:

  o *Role of stack diameter.* To evaluate whether the choice made for stack diameter strongly influenced results, ATSDR used a sensitivity analysis in which all hypothetical stacks were assigned a stack diameter of 0.001 meters. This value was selected based on dispersion modeling guidance published by the Texas Natural Resource Conservation Commission (now the Texas Commission on Environmental Quality) (TNRCC 1997). To evaluate this change, ATSDR compared model predictions using the two different stack diameters and found that the predictions differed marginally (171 µg/m^3 vs. 168 µg/m^3 at the point of maximum impact for one of the chemicals), even when stack diameters were changed by a factor of 1,000. Therefore, the dispersion modeling results were relatively insensitive to the inputs selected for diameters of the hypothetical stacks.

  o *Role of exit velocity.* The second round of sensitivity analyses for fugitive emissions sources considered the role of the exit velocity values entered into the model. ATSDR's modeling analysis considered 0.001 meters per second, which is essentially a passive release. This value was selected based on the past dispersion modeling conducted by IBM and on modeling guidance published by Texas regulators (TNRCC 1997). The sensitivity analysis considered the impact of increasing the exit velocities of all hypothetical stack sources by a factor of 1,000 to 1.0 meters per second (equal to 2.2 miles per hour). This evaluation also revealed only marginal changes (<2%) at the point of maximum impact due to the increased exit velocity, suggesting that the modeling results are relatively insensitive to considerable increases in exit velocities, at least in the range of 0.001 to 1.0 meters per second (and with other modeling parameters fixed at their proposed values).

  o *Modeling fugitive emissions hypothetical stacks versus volume sources.* Given the relative importance of fugitive emissions from the former IBM facility, ATSDR also investigated the significance of representing the fugitive emissions using hypothetical point sources versus volume sources. Based on past experience, ATSDR has seen both approaches used in evaluating source complexes similar to

those for the former IBM facility. To evaluate this scenario, ATSDR conducted a sensitivity analysis for TCA in which all fugitive emissions were represented as volume sources, using dimensions based on building sizes. For simulation year 1987, this analysis found that, when fugitive emissions were modeled as volume sources, the highest annual average concentration at the point of maximum impact was 13% lower than the predictions based on hypothetical point sources. Further, for the majority of receptors (>80%), representing the fugitive emissions as volume sources led to higher estimated concentrations in comparison to representing these sources as hypothetical points, but the magnitude of this increase was relatively small. Overall, these observations suggest that the decision to model fugitive emissions as hypothetical stacks resulted in estimated concentrations not substantially different from simulation results generated by representing fugitive emissions as volume sources.

Taken together, the sensitivity analyses show that several seemingly important assumptions made when developing the modeling protocol and the values selected for some model inputs actually had very little impact on the modeling results, at least for the chemicals, time frames, and receptors considered. Therefore, the sensitivity analyses confirm that these assumptions and input parameters appear to introduce very little uncertainty into the modeling results. While these results are encouraging, the sensitivity analyses did not consider every possible source of quantifiable uncertainty. Any uncertainty in the emission rates entered into the model, for instance, is expected to translate directly into the model outputs. While the accuracy of the emissions data cannot be quantified, this modeling analysis was limited to only those chemicals having facility-wide emissions data of a perceived high quality. The quality of these emissions data was assessed largely through judgment, considering observations such as concordance of emissions estimates among multiple documents that ATSDR accessed during its file reviews.

Though annual emissions data are believed to be reasonably accurate, uncertainties are likely far greater for the short-term emissions data. Actual peak emission rates were likely driven by process upsets, leaks, spills, and other unplanned releases, but detailed information (e.g., estimated emission rates) on such events is not available. To evaluate short-term air quality impacts, ATSDR's modeling simply assumed a constant emission rate over the entire year, based on the annual facility-wide emissions data. While no other defensible approaches were available to assess short-term exposures, this assumption very likely caused the modeling results to *underestimate* the short-term air quality impacts. ATSDR cannot further refine these short-term concentration estimates unless data exist on the magnitude of peak emission rates from specific stacks for the time frame of interest. Unfortunately, such insights are often times not available, especially for fugitive emissions sources and time frames more than 15 years ago.

While the sensitivity analyses generally justify several assumptions made in the modeling analyses, it is not ATSDR's intent to imply that the modeling results perfectly portray air quality impacts associated with IBM's past emissions. As noted previously, there are some uncertainties that cannot be quantified, such as those from model uncertainty and meteorologic data uncertainty. It would be more appropriate to characterize these modeling results as our best estimates of the incremental impact of IBM's emissions on local air quality for the years 1987 to 1993. Although these estimates are based on extensive information gathered during multiple

thorough reviews of files maintained by IBM and NYSDEC, the model outputs are estimates and might understate or overstate the actual air quality impacts that previously occurred. It is worth noting, however, that ATSDR's modeling predictions are reasonably consistent with those identified in IBM's previous modeling studies, particularly those documented in Appendix D.1 and D.2.

The previous discussion has focused largely on uncertainties. ATSDR's modeling also has several limitations, primarily as a result of the project scope defined early in this assessment. First, a limitation of the modeling is its temporal coverage. The modeling provides detailed insights on air quality impacts, but only for the 1987–1993 time frame. This health consultation includes a more complete account of the air exposure pathway, considering qualitative insights for earlier time frames based on information ATSDR gathered during file reviews. Second, the modeling addresses 14 chemicals, which is a very small subset of the number of chemicals that IBM previously used. However, this evaluation focused on the chemicals believed to be of greatest interest (due to their toxicity and emissions) and those for which the available information was judged to be sufficient to support modeling. Third, the modeling predicts the incremental effect that IBM's past emissions had on local air quality; emissions from other sources and background levels were not considered, as the next section addresses. None of these limitations necessarily weakens the modeling analysis, but the limitations are important to acknowledge such that modeling results are interpreted in proper context.

Table E-1. Stack Parameters Used in ATSDR's Modeling

Source	Stack Height (m)	Stack Diameter (m)	Exit velocity (m/s)	Exit temperature (K)
02010	22.6	0.42	21.61	294.3
04009	18.3	0.61	1.56	300.0
04010	18.9	0.41	24.40	296.9
18015	20.4	0.46	25.30	295.2
18397	6.1	0.30	0.76	297.6
18509	22.9	0.64	8.38	300.4
18570	21.0	0.46	8.23	299.8
18574	21.0	0.76	11.10	305.2
18576	19.8	0.66	7.01	299.8
18635	25.9	0.36	26.20	300.0
18636	22.6	0.71	4.16	305.2
18637	24.4	0.48	11.20	300.0
18638	24.4	0.71	11.90	305.2
18665	22.6	0.43	17.80	305.2
18674	30.2	0.91	8.56	297.0
18688	30.2	0.18	24.90	297.0
21006	18.9	0.22	10.45	294.3
41066	19.2	0.36	11.60	294.1
41149	18.3	1.02	10.60	295.2
41166	20.1	0.25	8.66	294.1
41174	18.3	0.56	3.26	302.6
41175	18.3	0.86	5.94	302.4
46101	18.3	0.04	8.66	298.7
47199	29.3	0.51	4.14	300.0
47213	28.0	0.51	3.90	295.2
57012	9.8	0.21	5.43	294.3
57018	10.7	0.87	3.93	295.4
94002	6.1	0.48	11.28	294.3
96029	12.2	0.51	9.32	294.1
25801	38.1	1.68	42.43	295.9
25803	35.1	0.46	10.10	296.3
25804	35.1	0.51	7.80	296.5
27307	11.9	0.10	21.03	294.3
27308	11.9	0.10	18.62	297.0

Table E-2. Modeling Results for 11 Chemicals with Estimated Air Quality Impacts Lower than Health-Based Comparison Values

Chemical	Year	Estimated Concentrations, by Averaging Time					
		Annual		24-Hour		1-Hour	
		µg/m^3	ppb	µg/m^3	ppb	µg/m^3	ppb
1,2-Dichlorobenzene	1988	1.3	0.2	6.1	1.0	23	3.9
Ethylbenzene	1987	1.1	0.3	5.1	1.2	19	4.5
Ethylene glycol	1990	0.5	0.2	2.5	1.0	9.7	3.8
Freon 113	1987	150	19	670	87	2,300	300
Methanol	1988	2.2	1.7	10	7.7	38	29
2-Methoxyethanol	1987	4.3	1.4	20	6.4	76	24
Methyl ethyl ketone	1988	7.5	2.6	35	12	130	45
Phenol	1991	0.2	0.1	1.0	0.3	3.9	1.0
tert-Butyl alcohol	1987	5.4	1.8	25	8.2	95	31
1,1,1-Trichloroethane	1987	170	31	670	87	2,300	300
Xylenes (total)	1987	7.7	1.8	36	8.2	140	31

Note: The table lists estimated concentrations for the offsite receptor believed to have the greatest air quality impacts in the year specified. Estimated concentrations at all other receptors and other years considered in the modeling analysis (1987–1993) can be assumed to be lower than the levels shown above.