# Health Consultation

# Evaluation of Non-Hodgkin's Lymphoma, Prostate Cancer, Stomach Cancer, and Thyroid Cancer Incidence in Watertown, Massachusetts and Adjacent Census Tracts 1982-1994

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## I. INTRODUCTION

In 1996, the Massachusetts Department of Public Health (MDPH), Bureau of Environmental Health Assessment (BEHA), released a health consultation for Watertown, MA (MDPH 1996). The health consultation was conducted under a cooperative agreement with the U.S. Agency for Toxic Substances and Disease Registry (ATSDR) and was completed at the request of several citizens' groups and legislative representatives from Watertown who petitioned ATSDR to evaluate health and environmental concerns. The primary community concerns focused on the possibility of a relationship between cancer incidence and environmental exposures associated with the presence of the Army Materials Technology Laboratory (AMTL), which is on the U.S Environmental Protection Agency's (EPA) National Priorities List (NPL). The NPL is EPA's list of uncontrolled or abandoned hazardous waste sites identified for possible long-term remedial action under the Federal Superfund.

In response to these concerns, MDPH reviewed the incidence of twelve cancer types for the years of 1982-1990. These cancer types included Hodgkin's disease, non-Hodgkin's lymphoma, leukemia, and cancers of the bladder, brain, breast, kidney, liver, lung, pancreas, stomach, and thyroid (MDPH 1996) and were evaluated for Watertown as a whole and for each of the four census tracts that further subdivide the town (CTs 3701, 3702, 3703, and 3704). Census tracts 3703 and 3704 are located adjacent to the AMTL site, a former arms manufacturing, storage, and materials research facility (see Figures 1 and 2).

The results of the 1996 health consultation revealed that Watertown as a whole did not experience statistically significant elevations for the twelve cancer types that were analyzed. Statistically significant elevations in individual census tracts, however, were found. The statistically significant elevations in specific census tracts were as follows:

- Bladder cancer in CT 3701 for males and for males and females combined.
- Non-Hodgkin's lymphoma (NHL) in CT 3704 for males and females combined.
- Stomach cancer in CT 3704 for males and females combined.

- Thyroid cancer in CT 3703 for females and for males and females combined.

In addition, the consultation noted that diagnoses for certain cancer types appeared concentrated in Watertown, including bladder cancer cases in CT 3701, NHL cases in CT 3703, and stomach cancer cases in CT 3704. Census tract 3701 is located on the western side of Watertown and is not near the AMTL site. The NHL cases in CT 3703 were also not located near the AMTL site. The stomach cancer cases in CT 3704 were located in a neighborhood near the AMTL site.

As a result of the 1996 Health Consultation, the MDPH/BEHA recommended a further evaluation of risk factor information and residential histories for the cancer types that appeared concentrated in Watertown. This work was completed in January 2000. The results of this analysis did not reveal any unusual patterns that suggest that environmental factors played a role in the occurrence of several types of cancer in Watertown census tracts (ATSDR 2000).

In addition to the follow-up work recommended in the Health Consultation, the Watertown AMTL Restoration Advisory Board (RAB), a committee established to help select the best remedies for restoring the site and to ensure community participation in this process, separately requested that the MDPH/BEHA update cancer incidence data for three cancer types NHL, stomach, and thyroid. The RAB also requested that prostate cancer be added to the updated investigation. The RAB raised concerns about these cancer types in Watertown, and in additional areas adjacent to and across the Charles River from Watertown, including Brighton/Allston (CTs 1.00, 2.01, 2.02, and 3.00), Cambridge (CTs 3542 and 3543), and Newton (CT 3731).

The locations of these census tracts in relation to Watertown and the AMTL site are depicted in Figure 2. In response to the RAB request, this report summarizes the additional analyses of these four cancer types in Watertown and adjacent census tracts in Brighton/Allston, Cambridge, and Newton.

## II. SITE BACKGROUND

The AMTL property is located on 36.5 acres of land in Watertown, Massachusetts, approximately five miles west of downtown Boston. The former mission of AMTL was materials development, structural integrity testing, solid mechanics, lightweight armor development, and manufacturing testing technology. The facility was established as the Watertown Arsenal in 1816 and was originally used for the storage, cleaning, repair, and issue of small arms and ordnance supplies. During the 1800s, this mission was expanded to include ammunition and pyrotechnics production, materials testing, and experimentation with paint, field and siege guns. Arms manufacturing continued at the facility until an operational phasedown was initiated in 1967. In 1960 the army constructed its first materials research nuclear reactor, which was used actively in molecular and atomic structure research activities until 1970, when it was deactivated. In September 1995, the AMTL was closed upon recommendation from the Secretary of Defense's ad hoc Commission on Base Realignment and Closure (ATSDR 1997).

Environmental investigations conducted at the AMTL site subsequent to its closure detected contamination at the property. Therefore, the AMTL site was proposed to the NPL in June 1993 and added to the list on May 31, 1994. Contamination in soil (e.g., metals, pesticides, polychlorinated biphenyls, and polycyclic aromatic hydrocarbon compounds) and groundwater (e.g., chlorinated solvents) beneath the AMTL site and the potential for site contaminants to migrate to the Charles River were factors in considering the site for the NPL. Specific environmental concerns focused on the potential for human exposure to contaminant releases from the site.

The Federal Facilities Assessment Branch of ATSDR prepared a Public Health Assessment (PHA) of the AMTL site that was released on February 21, 1997 (ATSDR 1997). The PHA evaluated opportunities for exposure to site-related contaminants. ATSDR concluded that opportunities for exposures to site-related contaminants (e.g., from past air emissions of depleted uranium) were not expected to result in health effects. For further details on ATSDR's assessment of environmental data related to the AMTL, see the PHA (ATSDR 1997).

## III. OBJECTIVES

This investigation is a descriptive evaluation of health outcome data for cancer. The primary focus in this report is to review cancer incidence for Watertown as a whole, and for the additional census tracts in towns adjacent to the AMTL. The intent of the investigation was to evaluate the temporal and geographic pattern of cancer in these areas, and the possible role that risk factors, including environmental factors, might have played in cancer incidence in this area.

Descriptive analyses of cancer incidence may indicate a pattern that suggests a common etiology is possible and can serve to identify areas where further public health investigations or actions may be warranted. Descriptive analyses may also help identify an excess of a well-established risk factor that is associated with a disease in a certain geographic area. However, descriptive assessments have certain inherent limitations. Only routine data collected at the time of each individual's cancer diagnosis are analyzed and information about personal risk factors (e.g. family history, hormonal events, diet) that may also influence cancer incidence is often limited and is not of historical nature. Therefore, it is beyond the scope of this investigation to determine any causal relationship or synergistic roles that risk factors (environmental or non-environmental) discussed in this report may have played in the development of cancer in the Watertown AMTL study region. The purpose of this investigation is to provide a comparison of the incidence of the cancers in Watertown and adjacent census tracts with the incidence of these cancers in the state of Massachusetts, and to report and discuss findings in the context of the available information to determine whether further investigation is warranted.

The specific objectives of this investigation were as follows:

- To evaluate the incidence of NHL, stomach, thyroid, and prostate cancers in Watertown by smaller geographic areas within the town (i.e., CTs 3701, 3702, 3703, and 3704) to determine if areas have higher or lower cancer rates;

- To evaluate the incidence of the four cancer types in smaller geographic areas adjacent to the AMTL site (i.e., Brighton/Allston CTs 1.00, 2.01, 2.02, and 3.00; Cambridge CTs 3542 and 3543; Newton CT 3731);

- To review available descriptive information reported by the Massachusetts Cancer Registry (MCR) for cancer cases in the Watertown AMTL study region related to risk factors for developing those cancers; and

- To discuss the results of this evaluation in the context of the available scientific and medical literature on cancer to determine whether future investigation or public health action is warranted.

## IV. METHODS FOR ANALYZING CANCER INCIDENCE DATA

### A. Case Identification

The observed number of cancer cases in this evaluation included all primary site cases of stomach cancer, prostate cancer, thyroid cancer, and NHL reported to the Massachusetts Cancer Registry (MCR) diagnosed in Watertown residents and residents of adjacent census tracts between 1982-1994. Cases were selected for inclusion based on the address reported to the hospital or reporting facility at the time of diagnosis.

The MCR, a population-based surveillance system, began collecting information on Massachusetts residents diagnosed with cancer in the state in 1982. All newly diagnosed cancer cases among Massachusetts residents are required by law to be reported to the MCR within six months of the date of diagnosis (M.G.L. c.111s.111B). Cancer incidence data were evaluated for the years 1982-1994, which was the time period for which complete data were available at the time analyses for this investigation were initiated. As noted previously, the 1996 health consultation evaluated data for the time period 1982-1990 for three of the four cancer types reviewed here for Watertown and its individual census tracts. These previously completed analyses are included here to complement the current analysis that comprises additional years of data and census tracts

from adjacent communities. In addition, a review of incidence data for the years 1994-1998 is included for the town of Watertown as a whole.

Cancer is not just one disease but describes a variety of diseases associated with abnormal cell and tissue growth. Primary site (location in the body where the disease originated) and histology (tissue or cell type) classify the different cancer types. Epidemiological studies have revealed that different types of cancer are individual diseases with separate causes, risk factors, characteristics and patterns of survival (Bang 1996). Therefore, the cancer types evaluated in this report were evaluated separately.

At the request of the RAB, four cancer types were evaluated in this investigation. These include cancers of the stomach, prostate, and thyroid as well as, non-Hodgkin's lymphoma (NHL). These cancer types were selected for evaluation based on community concerns about suspected increases in these cancers. Only primary site cancers (i.e., cancers originating in the stomach, prostate, thyroid, or lymphatic system) were included in this evaluation. Therefore, cancers that occur as the result of the metastases or the spread of a primary site cancer to another location in the body are not considered as a separate cancer and were, therefore, not included.

Occasionally, the MCR research file may contain duplicate reports of cases. The data discussed in this report have been controlled for duplicate cases by excluding them from the analyses. Duplicate cases are additional reports of the same primary site cancer case. The decision that a case was a duplicate and should be excluded from the analyses was made by the MCR after consulting with the reporting hospital/diagnostic facility and obtaining additional information regarding the histology and/or pathology of the case. However, reports of individuals with multiple primary site cancers were included. A multiple primary cancer case is defined by the MCR as a new cancer of the same cell type (histology) as an earlier cancer, if diagnosed in the same primary site (original location in the body) more than two months after the initial diagnosis (MCR 1996).

## B. Calculation of Standardized Incidence Ratios (SIRs)

To determine whether elevated numbers of cancer cases have occurred in Watertown, its census tracts, or adjacent CTs evaluated in this report, cancer incidence data were analyzed by age-group and gender to compare the observed number of newly diagnosed cancer cases in each census tract to the number that would be expected based on the statewide cancer incidence. Standardized incidence ratios (SIRs) were calculated for the period 1982-1994 for each of the four cancer types for the eleven census tracts and for Watertown as a whole. SIRs were also calculated for two smaller time periods, 1982-1986 and 1987-1994, in order to evaluate temporal trends in cancer incidence.

Because accurate age group and gender specific population data are required to calculate SIRs, the census tract is the smallest geographic area for which cancer rates can be accurately calculated. Specifically, a census tract (CT) is a smaller statistical subdivision of a county. Census tracts usually contain between 2,500 and 8,000 persons and are designed to be homogenous with respect to population characteristics (US DOC 1990). The location and boundaries of Watertown census tracts are illustrated in Figure 2. Also included in this evaluation are seven census tracts located in three towns in close proximity to the AMTL. These include Brighton/Allston CTs 1.00, 2.01, 2.02, and 3.00; Cambridge CTs 3542 and 3543; and Newton CT 3731. The locations of these census tracts are also shown in Figure 2.

In order to calculate incidence rates, it is necessary to obtain accurate population information. The population figures used in this analysis were interpolated based on 1980 and 1990 U.S. census data for each census tract in the Watertown AMTL study region (Bureau of the Census 1980, 1990). Midpoint population estimates were calculated for each time period evaluated. To estimate the population between census years, an assumption was made that the change in population occurred at a constant rate throughout the ten-year interval between each census. According to the 1980 U.S. census, Watertown was subdivided into four census tracts (U.S. DOC, 1980). During the 1990 U.S. census, the Census Bureau further divided Watertown CT 3701 producing five CTs in Watertown. However, for the purposes of this study, in order to evaluate cancer

incidence by census tract over time, the split tracts in 1990 (CTs 3701.01 and 3701.02) were combined to be consistent with data from the 1980 census.

## C. Explanation/Interpretation of an SIR

An SIR is an estimate of the occurrence of cancer in a population relative to what might be expected if the population had the same cancer experience as some larger comparison population designated as "normal" or average. Usually, the state as a whole is selected to be the comparison population. Using the state of Massachusetts as a comparison population provides a stable population base for the calculation of incidence rates. Due to the instability of incidence rates based on small numbers of cases, SIRs were not calculated when fewer than five cases were observed.

Specifically, an SIR is the ratio of the observed number of cancer cases to the expected number of cases multiplied by 100. An SIR of 100 indicates that the number of cancer cases observed in the population evaluated is equal to the number of cancer cases expected in the comparison or "normal" population. An SIR greater than 100 indicates that more cancer cases occurred than expected and an SIR less than 100 indicates that fewer cancer cases occurred than expected. Accordingly, an SIR of 150 is interpreted as 50% more cases than the expected number; an SIR of 90 indicates 10% fewer cases than expected.

Caution should be exercised, however, when interpreting an SIR. The interpretation of an SIR depends on both the size and the stability of the SIR. Two SIRs can have the same size but not the same stability. For example, an SIR of 150 based on four expected cases and six observed cases indicates a 50% excess in cancer, but the excess is actually only two cases. Conversely, an SIR of 150 based on 400 expected cases and 600 observed cases represents the same 50% excess in cancer, but because the SIR is based upon a greater number of cases, the estimate is more stable. It is very unlikely that 200 excess cases of cancer would occur by chance alone.

The reader may want to compare one census tract's SIR with another, or compare an SIR for a cancer type in Watertown with an SIR for that cancer type in another town.

Such a comparison, however, is not appropriate or meaningful because each census tract is age-adjusted to a standard (i.e., the state cancer rate and the specific age distribution of the tract's population). The SIR values are estimates of cancer incidence that serve as indicators of incidence after adjusting for the age distribution of a population. Small differences in a population's age distribution can be sufficient to affect some change in SIR values. Therefore, the comparison of SIRs in tracts with differences in their age distribution for the purpose of stating which tract has a higher SIR would result in misleading information and possibly incorrect conclusions.

## D. Calculation of 95% Confidence Interval

To determine if the observed number of cases is significantly different from the expected number or if the difference may be due solely to chance, a 95% confidence interval (CI) was calculated for each SIR (Rothman and Boice 1982). A 95% CI assesses the magnitude and stability of an SIR. Specifically, a 95% CI is the range of estimated SIR values that have a 95% probability of including the true SIR for the population. If the 95% CI range does not include the value 100, then the study population is significantly different from the comparison or "normal" population. "Significantly different" means there is less than 5% percent chance that the observed difference is the result of random fluctuation in the number of observed cancer cases.

For example, if a confidence interval does not include 100 and the interval is above 100 (e.g., 105-130), then there is a statistically significant excess in the number of cancer cases. Similarly, if the confidence interval does not include 100 and the interval is below 100 (e.g., 45-96), then the number of cancer cases is statistically significantly lower than expected. If the confidence interval range includes 100, then the true SIR may be 100, and it cannot be concluded with sufficient confidence that the observed number of cases is not the result of chance and reflects a real cancer increase or decrease. Again, as a result of the instability of incidence rates based on small numbers of cases, statistical significance was not assessed when fewer than five cases are observed.

In addition to the range of the SIR estimates contained in the confidence interval, the width of the confidence interval also reflects the stability of the SIR estimate. For

example, a narrow confidence interval (e.g., 103-115) allows a fair level of certainty that the calculated SIR is close to the true SIR for the population. A wide interval (e.g., 85-450) leaves considerable doubt about the true SIR, which could be much lower than or much higher than the calculated SIR. This would indicate an unstable statistic.

## E. Determination of Geographic Distribution

The geographic distribution of cancer cases in Watertown and the adjacent CTs evaluated in this report was determined using available address information from the MCR indicating residence at the time of diagnosis. This information was mapped for each individual using a computerized geographic information system (GIS) (MapInfo 1996). This allowed for the assignment of census tract location for each case as well as an evaluation of the spatial distribution of cases at a smaller geographic level (i.e., neighborhoods). The geographic distribution was assessed using a qualitative evaluation of the point pattern of cases within the town and within each census tract evaluated. In instances where the address information was incomplete (i.e., did not include specific streets or street numbers), efforts were made to research those cases using telephone books and town residential lists issued within two years of an individual's diagnosis.

## F. Demographic Analysis

For the purposes of this investigation, demographic trends were reviewed in Watertown and the adjacent census tracts involved in the study. Data from the U.S. Census Bureau was used to evaluate demographic trends in age, race, sex, percent educated beyond high school, median household income, and percent below poverty level (Bureau of the Census 1990) (see Table 1). It is important to note that even though these census tracts are located adjacent to each other, it is difficult to give a comparative analysis of cancer incidence results between towns or census tracts that are not demographically related. Socioeconomic and demographic variables can affect the outcome of cancer incidence data. For instance, studies have consistently shown an association of stomach cancer with low socioeconomic status based on census tract information, education, family income, or occupation (reviewed in Nomura 1996). As

previously stated, data for Watertown and the adjacent CTs shows that these areas are not demographically similar and therefore a comparative analysis of SIRs between CTs is not appropriate.

### G. Evaluation of Cancer Risk Factors

Research has shown that there are more than 100 different types of cancer, each with different causative or risk factors. Environmental contamination has been associated with certain types of cancer while a number of cancer types have been associated with behavioral risk factors such as tobacco use and diet. However, cancer may also be caused by one or several factors acting over time. Also, many cancers have a lengthy latency period (i.e., the interval between first exposure to a disease-causing agent and the appearance of symptoms of the disease [Last 1995]). For most cancers, the latency period can range from 10 to 30 years and in some cases may be more than 40 to 50 years (Bang 1996; Frumkin 1995). The MCR routinely collects data related to risk factors for individuals diagnosed with cancer. The available risk factor information from the MCR was evaluated for those cancers found to be elevated in this analysis (e.g., age, smoking status, occupation, etc.). Information about personal risk factors (e.g., family history, hormonal events, diet, etc.) which may also influence the development of cancer is not collected by the MCR and was therefore not evaluated in this investigation.

## V. RESULTS OF CANCER INCIDENCE ANALYSIS

The following sections present cancer incidence rates for Watertown as a whole, Watertown census tracts, and the seven census tracts located in neighboring cities adjacent to the site. Figure 2 depicts the location of the census tracts studied in this investigation. The census tract-specific analyses help in understanding whether the incidence of cancers observed town wide or region wide may be explained by an increase or decrease in cases in a particular geographic area of a particular town.

## A. Cancer Incidence in Watertown

This section presents results of the cancer incidence analysis for Watertown as a whole and for each census tract evaluated. Tables 2 through 6 summarize cancer incidence data for Watertown for three different periods: the 13-year period 1982-1994 and the two smaller time periods, 1982-1986 and 1987-1994. Table 2 reviews cancer incidence data townwide for the three different time periods while Tables 3 through 6 summarize cancer incidence data for Watertown CTs 3701, 3702, 3703, and 3704 for the same time periods.

### *1. Cancer Incidence in Watertown as a Whole (Table 2)*

During the 13-year period 1982-1994, two of the four cancer types evaluated in Watertown occurred statistically significantly more often than expected: NHL (98 cases observed vs. 75.8 cases expected, SIR=129, 95% CI=105-158) and prostate cancer (293 cases observed vs. 246.3 expected, SIR=119, 95% CI=106-133) (see Table 2). NHL also occurred more often than expected among males and among females during 1982-1994 but neither elevation was statistically significant. When examined by the two smaller time periods, NHL was elevated for each time period among males and females combined, among males, and among females. None of these elevations was statistically significant.

The elevation in prostate cancer was primarily the result of a statistically significant elevation that occurred during the 1987-1994 time period. During this period there was a 28% increase in prostate cancer above the statewide incidence (224 observed vs. 174.7 expected, SIR=128, 95% CI=112-146). During the earlier time period, 1982-1986, prostate cancer occurred about as expected based on the state rate (69 observed vs. approximately 70 expected).

During 1982-1994, thyroid cancer occurred more often than expected among males and females combined (26 cases observed vs. 19.5 expected). This elevation was due to an elevation among females (21 cases observed vs. 14.3 expected). Neither elevation was statistically significant. Thyroid cancer among males occurred approximately equal to expected. When examined by smaller time periods, thyroid

cancer occurred about as expected during 1982-1986 and was elevated during 1987-1994. Again, this elevation was due to an increase in the incidence of this cancer type among females.

Stomach cancer occurred more often than expected for both males and females in all time periods evaluated. About one or two more cases over the expected number occurred among males for each time period while about three to five more cases occurred among females. No elevation was statistically significant.

As noted previously, townwide cancer incidence data from the MCR for the years 1994-1998 were reviewed for Watertown as a whole (MDPH, 2001). During these years, the incidence of prostate cancer was statistically significantly elevated with respect to the state rate in Watertown (147 cases observed vs. approximately 108 expected, SIR=136). Townwide elevations in NHL and thyroid cancer were also observed among males and females combined as well as among males and females when evaluated separately by gender, however, these elevations were not statistically significant. Among males and females combined, 39 individuals were diagnosed with NHL where approximately 31 cases were expected and 15 individuals were diagnosed with thyroid cancer where approximately 11 cases were expected. Stomach cancer occurred at about the rate expected (13 cases observed vs. approximately 14 expected).

*2. Cancer Incidence in Census Tract 3701 (Table 3)*

Census tract 3701 is located in the western portion of Watertown, removed from the AMTL site. During the 13-year period 1982-1994, an elevation occurred in the incidence of NHL in CT 3701 (39 cases observed vs. approximately 31 expected). This elevation was primarily due to an increase of approximately 7 cases above the expected number among males and females combined during the 1987-1994 time period (28 cases observed vs. 20.6 expected). Neither elevation was statistically significant. One more individual than expected was diagnosed with NHL during 1982-1986 (11 cases observed vs. 10 expected).

Prostate cancer occurred more often than expected during 1982-1994 (116 cases observed vs. approximately 99 expected), but this elevation was not statistically significant. The elevation was due to a statistically significant elevation of prostate cancer during 1987-1994 (94 cases observed vs. 71.3 expected, SIR=132, 95% CI=107-161). Prostate cancer occurred less often than expected during the earlier time period 1982-1986 (22 cases observed vs. approximately 27 expected).

Both stomach and thyroid cancers occurred slightly more often than expected during 1982-1994 in CT 3701. However, these elevations represented approximately two cases above the expected number for each cancer type (22 stomach cancer cases observed vs. approximately 20 expected and 10 thyroid cancer cases observed vs. approximately 8 expected). These slight elevations were the result of lower-than-expected rates during the earlier time period 1982-1986 and higher-than-expected rates during 1987-1994.

*3. Cancer Incidence in Census Tract 3702 (Table 4)*

Census tract 3702 is located in the northern region of Watertown and, like CT 3701, does not border the AMTL site. During the time period 1982-1994, cancer incidence in this census tract occurred approximately at or near the expected rates for stomach and thyroid cancers. Prostate cancer was statistically significantly elevated (94 cases observed vs. 67.3 cases expected, SIR=140, 95% CI=113-171). The observed elevation was primarily due to the statistically significant elevation during 1987-1994 (72 cases observed vs. 47.1 cases expected, SIR=153, 95% CI=120-193). During the earlier time period, 1982-1986, the incidence of prostate cancer was about as expected (22 cases observed vs. approximately 20 cases expected, SIR=110).

In CT 3702, NHL occurred slightly more often than expected among males and females combined during 1982-1994 (24 cases observed vs. approximately 20 expected). This elevation was due to an excess of 5 cases diagnosed among females (15 cases observed vs. 10 expected). Neither elevation was statistically significant. During the two smaller time periods, excesses of approximately one to three cases occurred among males and females combined, with elevations primarily due to slightly higher incidence rates

among females in this census tract. Again, these elevations were the result of small increases above the expected number and were not statistically significant.

*4. Cancer Incidence in Census Tract 3703 (Table 5)*

Census tract 3703 is located in the eastern section of Watertown and borders the AMTL site. Between 1982-1994, cancer incidence was approximately at or near the expected rates among males, females, and males and females combined for three out of the four cancer types evaluated in census tract 3703. Among males and females combined during this time period, the incidence of NHL, prostate cancer, and stomach cancer was lower than expected (14 cases of NHL observed vs. approximately 15 expected; 47 cases of prostate cancer observed vs. approximately 49 expected; and 8 cases of stomach cancer observed vs. approximately 10 expected). Although not statistically significant, thyroid cancer occurred more often than expected in this census tract (7 cases observed vs. 3.6 expected), with approximately one excess case among males and two excess cases among females. Similar trends were observed when results were evaluated by the two smaller time periods, 1982-1986 and 1987-1994.

*5. Cancer Incidence in Census Tract 3704 (Table 6)*

Cancer incidence for the four cancer types in CT 3704, located in the southern portion of Watertown adjacent to the AMTL site, generally occurred at a greater rate than expected based on state rates (refer to Table 6). During the 13-year time period 1982-1994, NHL occurred approximately twice as often as expected in this census tract. This result was statistically significant for males and females combined (21 cases observed vs. 10.6 expected, SIR= 197, 95% CI=122-302) and for males (11 cases observed vs. 5.1 cases expected, SIR=217, 95% CI=108-389).

Stomach cancer incidence was also statistically significantly elevated at about twice the expected rate for males and females combined for the time period of 1982-1994 (13 cases observed vs. 6.4 cases expected, SIR= 204, 95% CI=109-350). However, the relatively small number of cases observed and the width of the confidence interval suggest that, although statistically significant, this SIR is somewhat unstable. The

observed elevation was due to elevated rates among both males and females when evaluated separately. Among males, 7 cases of stomach cancer were observed versus 3.5 expected (SIR=198). Among females, 6 cases were observed versus 2.8 expected (SIR=212). However, neither elevation achieved statistical significance.

Prostate and thyroid cancers occurred more often than expected in CT 3704 (36 cases of prostate cancer observed vs. 31.1 expected and 5 cases of thyroid cancer observed vs. 3.2 expected) but the elevations observed were not statistically significantly different from the expected incidence.

Evaluation by the two smaller time periods, 1982-1986 and 1987-1994, revealed that the elevated rate for NHL among males and females combined observed for the entire 13-year time period were primarily due to a statistically significant elevation for the earlier time period 1982-1986 (9 cases observed vs. 3.7 cases expected, SIR=243). NHL was also elevated during the later time period, 1987-1994 (12 cases observed vs. 7 expected), but this elevation was not statistically significant.

When the incidence of stomach cancer was evaluated by smaller time periods, the incidence of stomach cancer was higher in 1982-1986 (7 cases observed vs. approximately 3 expected) than during the later time period 1987-1994 (6 cases observed vs. approximately 4 expected). The elevation in prostate cancer observed during 1982-1994 was the result of less than three additional cases over the expected number during each of the two smaller time periods. Finally, the elevated rate of thyroid cancer in CT 3704 during the 13-year period 1982-1994 can be attributed to an excess of approximately two cases during 1987-1994.

## B. Cancer Incidence in Brighton/Allston

Tables 7 through 10 summarize the results of cancer incidence analysis for the four CTs (1.00, 2.01, 2.02, and 3.00) evaluated in Brighton/Allston, which is part of Boston. These census tracts were chosen for evaluation at the request of the Watertown AMTL RAB due to their proximity to the AMTL site. They are located southeast of the Watertown CTs that border the AMTL site, across the Charles River (see Figure 2). The

following sections present results for the census tracts evaluated in the Brighton/Allston area.

*1. Cancer Incidence in Census Tract 1.00 (Table 7)*

In CT 1.00, the incidence of stomach, prostate, and thyroid cancer occurred approximately at or near the expected rates for all three time periods examined and for both genders. During the overall time period 1982-1994, 4 individuals were diagnosed with stomach cancer as expected, 19 individuals wee diagnosed with prostate cancer while 21 cases were expected, and one individual was diagnosed with thyroid cancer while about two cases were expected. The incidence of NHL was about as expected for the overall period 1982-1994 and the earlier time period 1982-1986. However, during the time period 1987-1994 there was a statistically significant elevation of NHL among males (7 cases observed vs. 2.4 cases expected, SIR=288, 95% CI=115-593) in this area of Brighton/Allston. However, the number of cases was relatively small and the fairly wide 95% confidence interval (115-593) indicates that this SIR is somewhat unstable. In addition, no cases of NHL among females were reported during 1982-1994, where 3.3 cases were expected.

*2. Cancer Incidence in Census Tract 2.01(Table 8)*

In census tract 2.01, cancer incidence for stomach, prostate, thyroid and NHL occurred approximately at or near the expected rates for all three time periods examined and for both genders. During the 13-year period 1982-1994, 14 cases of prostate cancer were observed versus 18.9 cases expected (SIR=74), however, this result was not statistically significant. The incidence of prostate cancer was lower than expected in both smaller time periods.

*3. Cancer Incidence in Census Tract 2.02 (Table 9)*

Results for CT 2.02 revealed that NHL and thyroid cancer occurred approximately at or near the expected rates for all three time periods examined and for both genders. Although not statistically significant, stomach cancer occurred slightly more often than expected based on statewide rates during 1982-1994 (6 cases observed

vs. 4.2 cases expected). This was primarily due to more cases diagnosed among males in this census tract (4 cases observed vs. 2.4 expected). Prostate cancer was slightly elevated during the 13-year period, however, this was based on less than three additional cases above the expected number and was not statistically significant. The slight elevation in the number of prostate cancer cases can be attributed to an excess of less than three cases during the later time period, 1987-1994.

*4. Cancer Incidence in Census Tract 3.00 (Table 10)*

NHL and stomach cancer were diagnosed approximately at or near the expected rates among males, females, and males and females combined for all three time periods evaluated in census tract 3.00. Although not statistically significant, thyroid cancer occurred slightly more often than expected during 1982-1994 (5 cases observed vs. 3.7 cases expected). This elevation can be attributed to a slight elevation in thyroid cancer among females in CT 3.00 (4 cases observed vs. 2.7 expected). The incidence of prostate cancer was lower than expected (32 cases observed vs. 37.5 cases expected) in this area of Brighton/Allston, however, this result was not statistically significant.

## C. Cancer Incidence in Cambridge

Tables 11 and 12 present the results of cancer incidence analysis for CTs 3542 and 3543 in Cambridge. These census tracts are located to the northeast, directly adjacent to Watertown CT 3703, which borders three sides of the AMTL site (located in the southwest corner of CT 3703). The results of the Cambridge census tract analyses are summarized below.

*1. Cancer Incidence in Census Tract 3542 (Table 11)*

In CT 3542 cancer incidence for stomach, thyroid and NHL was approximately at or lower than the expected rates for all three time periods examined and for both genders. During 1982-1994, prostate cancer occurred slightly more often than expected (32 cases observed vs. 28.2 expected), due to an elevation during the earlier time period 1982-1986 (11 cases observed vs. 7.5 expected). However, neither elevation was statistically

significant. The incidence of prostate cancer during the later time period 1987-1994 was approximately equal to the expected rate (21 cases observed vs. 20.6 cases expected).

NHL occurred less often than expected during 1982-1994 (3 cases observed vs. 8 cases expected), but this difference was not statistically significant. The incidence of stomach cancer was lower than expected based on statewide rates (2 cases observed vs. 5.3 cases expected). This was primarily due to the fact that no cases of stomach cancer occurred among males in this CT during 1982-1994 while approximately 3 cases were expected.

*2. Cancer Incidence in Census Tract 3543 (Table 12)*

In census tract 3543, for the time period 1982-1994, the incidence rates of all cancer types evaluated were approximately at or near the expected rates for all three time periods examined and for both genders. The difference between the expected and the observed numbers of cases for all cancer types, all time periods, and both genders was no more than one or two cases.

## D. Cancer Incidence in Newton

Table 13 summarizes the results of cancer incidence analysis for Newton CT 3731. This census tract is located across the Charles River, to the southwest of Watertown CTs 3703 and 3704, the area that includes the AMTL site.

*1. Cancer Incidence in Census Tract 3731 (Table 13)*

In census tract 3731 there were no statistically significant elevations of any of the four cancer types evaluated. The incidence of stomach cancer was elevated for males and females combined between 1982-1994 (10 cases observed vs. 5.5 cases expected, SIR=182). However, this elevation was not statistically significant (95% CI=87-335) and was the result of small increases above the expected number of cases (i.e., three or less) during the smaller time periods 1982-1986 and 1987-1994. NHL was also elevated for males and females combined between 1982-1994 (12 cases observed vs. 9.3 cases expected, SIR=130). The slight elevation in NHL was primarily the result of an elevation

in this cancer type among females during 1987-1994 (7 cases observed vs. 3 cases expected). Neither elevation was statistically significant.

Prostate cancer occurred about as or less often than expected across all three time periods evaluated in CT 3731. Four cases of thyroid cancer occurred versus approximately 3 expected during 1982-1994. This cancer type was slightly elevated during the earlier time period 1982-1986 (3 cases observed vs. approximately 1 expected) while one fewer case than expected occurred during the later time period 1987-1994.

## VI. EVALUATION OF CANCER RISK FACTOR INFORMATION

As previously mentioned, cancer is a term that describes a variety of diseases. As such, epidemiological studies have shown that different cancer types have separate causes, patterns of incidence, risk factors, characteristics and trends in survival.

Available case information related to gender, race, and age was reviewed for each of the cancer types evaluated in the study region (i.e., NHL, thyroid cancer, stomach cancer, and prostate cancer) to assess whether an atypical pattern exists among cases diagnosed in the area under investigation. In addition, smoking status and occupation were reviewed for census tracts with statistically significant elevations of cancer. Although the incidence of stomach cancer is associated with lower socioeconomic status (Nomura 1996), neither social class, income, nor education level appear to be important risk factors for thyroid cancer, prostate cancer, or NHL (Ron 1996; and Ross and Schottenfeld 1996; Scherr and Mueller 1996).

Some epidemiological investigations have indicated that certain gender and ethnic groups experience increases or decreases in the incidence of a particular cancer type. Review of trends in cancer incidence among racial or gender groups allows for the determination of patterns that may be indicative of risk factors for increased cancer (i.e., differences in personal habits, dietary practices, education and environmental exposures). Although SIRs were not calculated for different racial groups because of the small numbers of cases in non-white groups, the case distribution for the four cancer types evaluated was reviewed.

In addition, age is a risk factor in many cancers, including NHL, thyroid cancer, stomach cancer, and prostate cancer. As noted above, town and census tract SIRs were calculated after adjusting for the age distribution of the population. In addition, age group-specific SIRs were calculated for Watertown to evaluate cancer incidence in comparison to age group-specific rates for the state of Massachusetts as a whole. A review of age group specific SIRs for each census tract was not possible because of the small numbers of cases in each group. However, where there was a statistically significant elevation of cancer cases in a particular census tract, the distribution of cases by age was reviewed.

Tobacco use is a risk factor in many cancers, including NHL, prostate cancer, and stomach cancer. The smoking status of individuals in Watertown and adjacent census tracts diagnosed with these cancers during the years 1982-1994 was reviewed.

Occupational information as reported to the MCR was reviewed for those cancer types that have been associated with exposures in specific occupations. This information was reviewed in an attempt to determine the likelihood that occupational factors may have played a role in the occurrence of cancer in Watertown and adjacent CTs in Brighton/Allston, Cambridge, and Newton. It should be noted that occupational data reported to the MCR are limited to job title and do not include specific job duty information that could further define exposure potential for individual cases. Further, these data are often incomplete as cases can be reported as unknown, at home, or retired.

The following sections describe the results of the analysis of available risk factor information.

## A. Non-Hodgkin's Lymphoma

In Massachusetts, the incidence of NHL increased by 50% from 1982 to 1997 (MCR 1997, 2000). Gender, race, age, smoking status, and environmental exposure as well as HIV infection and other immune deficiencies are all possible risk factors for NHL.

*1. Gender/Race Distribution*

Among all NHL types combined there is a greater male to female ratio and white to black ratio (NCI 1996). Demographic data for Watertown show that the town is predominantly Caucasian (96%) and that females make up about 55% of the population (see Table 1). Watertown as a whole exhibited a statistically significant elevation in NHL incidence during the period 1982-1994. The cases were predominantly Caucasian and both males and females experienced elevations in NHL incidence of similar magnitude (approximately 30% more cases than expected). However, the pattern of NHL incidence in individual Watertown CTs varied: in CT 3701, the elevated incidence of NHL was of similar magnitude for both males and females; in CT 3702, the incidence of NHL was lower than expected among males while females experienced approximately 50% more cases than expected; in CT 3703, the incidence of NHL was lower than expected among females but higher than expected among males; and in CT 3704, both males and females experienced higher than expected rates of NHL with males experiencing a statistically significant elevation (SIR=217, 95% CI=108-389) during 1982-1994.

All 7 cases of NHL that were observed in Brighton/Allston CT 1.00 between 1987 and 1994 occurred in Caucasian males (SIR=288, 95% CI=115-593). Both males and females experienced NHL approximately at or near the expected rates in other census tracts in Brighton/Allston (i.e., CTs 2.01, 2.02, and 3.00). In Cambridge CT 3542, NHL occurred approximately half as often as expected among both males and females during 1982-1994. In Cambridge CT 3543, NHL occurred less often than expected among males and approximately at the expected rate among females. Finally, in Newton CT 3731, males experienced NHL at a lower rate than expected while females experienced approximately 70% more cases than expected during 1982-1994, however this elevation was based on three additional cases over the expected number. Individuals diagnosed with NHL in Watertown and adjacent census tracts in Brighton/Allston, Cambridge, and Newton were predominantly Caucasian.

*2. Age Distribution*

NHL occurs at all ages, however the incidence of this cancer generally increases with age. In Watertown overall and in the two census tracts with statistically significant elevations in NHL (i.e., CT 3704 and Brighton/Allston CT 1.00), the incidence of this disease also displayed an increasing pattern with increasing age; 61% of Watertown cases were age 65 years or older. Age-specific incidence rates indicate that the elevation in NHL incidence in Watertown does not appear to be the result of an elevation among any one age group. Elevations compared to the state rate were observed in all age groups, however, the largest increases in NHL incidence in Watertown between 1982 and 1994 occurred in the 20-44 and 65-74 age groups. A similar pattern was observed in Watertown CT 3704.

In Brighton/Allston CT 1.00, all age groups experienced NHL at lower than expected rates except individuals between the ages of 65 and 74 (5 cases observed vs. 1.9 expected). The statistically significant elevation in NHL cases among males for this CT during 1987-1994 can most likely be attributed to the increase in this age group. In general, in Brighton/Allston CTs 1.00, 2.01, 2.02, and 3.00, Cambridge CTs 3742 and 3743, and Newton CT 3731, the incidence of NHL cases was higher with increasing age, which is consistent with the age pattern for this cancer. However, in Newton CT 3731, the incidence of NHL among individuals in the 20-44 age group was approximately two times greater than expected based on state rates (4 cases observed vs. approximately 2 expected).

*3. Smoking Status*

Although a clear relationship has not been established, some studies have found a positive association with the incidence of NHL and smoking (Brown et al. 1992, Linet et al. 1992, Tatham net al. 1997). Available information on smoking habits was reviewed for each of the individuals diagnosed with NHL in Watertown. The percentage of individuals diagnosed with NHL who reported themselves as either a current or former smoker at the time of their diagnosis was very similar in both Watertown and Massachusetts (see Figure 3A). Approximately 37% of individuals diagnosed with NHL

in Watertown and 36% in Massachusetts reported themselves as a current or former smoker. In addition, the number of cases for which smoking status was unknown was similar for the town and the state. Of the individuals in Watertown with known smoking status, 47% were current or former smokers. In Brighton/Allston CTs 1.00, 2.01, 2.02, and 3.00, approximately 42% of individuals diagnosed with NHL were current or former smokers. Smoking status was unknown in 26% of cases. Of those with known smoking status, approximately 57% reported being current or former smokers at the time of diagnosis. In Cambridge CTs 3542 and 3543, 20% were current or former smokers. However, smoking status was unknown for half of the cases. Of those with known smoking status, the percentage of current or former smokers was 40%. Finally, in Newton CT 3731, 50% of individuals diagnosed with NHL reported themselves as either current or former smokers. Only 2 out of the 12 cases had unknown smoking status. Of the individuals with known smoking status, 60% were current or former smokers.

*4. Occupation*

Some occupations have also been associated with an increased risk of developing NHL, specifically occupations related to chemicals or agriculture. Farmers, herbicide and pesticide applicators, and grain workers appear to have the most increased risk (Tatham et al. 1997; Zahm 1990, 1993).

Review of available occupational information for each of the NHL cases in Watertown revealed that 36% of the 98 cases had a reported occupation as "retired," "housewife," or "at home." Occupation was unknown for an additional 15% of cases. The occupational data for the remaining cases did not indicate any jobs associated with an increased risk of NHL, with the possible exception of three individuals who were hairdressers. Analysis of occupational data for NHL cases in census tracts adjacent to Watertown (i.e., Brighton/Allston CTs 1.00, 2.01, 2.02, and 3.00; Cambridge CTs 3542 and 3543; and Newton CT 3731) also did not reveal any jobs associated with an increased risk of this disease. However, as noted above, MCR data are limited to job title only and does not include specific information related to job duties. Therefore, it could

not be determined if occupation may have played a role in the development of NHL among these individuals.

## B. Prostate Cancer

Cancer of the prostate is the most common cancer among American men, accounting for approximately 31% of all male cancer cases. An estimated 198,100 new cases occur per year in the U.S. and African American men are at least 50% more likely to develop prostate cancer than men of any other racial and ethnic group (ACS 2001). In addition to race, age is a major risk factor for prostate cancer. Other possible risk factors include tobacco use, a diet high in fat, and occupational exposures (e.g., exposures associated with rubber companies).

### *1. Gender/Race Distribution*

Prostate cancer was statistically significantly elevated for Watertown as a whole in the time periods of 1982-1994 and 1987-1994. The MCR also reported that prostate cancer was statistically significantly elevated for Watertown as a whole during 1994-1998. Analysis of case data for the 1982-1994 period showed that the cases were predominantly Caucasian. The racial breakdown of individuals in Watertown diagnosed with prostate cancer is as follows: 95% Caucasian, 1% African American, and 4% unknown. The large percentage of Caucasian individuals with prostate cancer is most likely attributed to the fact that 96% of the male population in Watertown is Caucasian. The racial distribution of individuals with prostate cancer was similar in adjacent census tracts in Brighton/Allston, Cambridge, and Newton. In Brighton/Allston CTs 1.00, 2.01, 2.02, and 3.00, 92% of individuals with prostate cancer were Caucasian, two individuals were African American, two were Chinese, one was Hispanic, and two were of unknown race. In Cambridge, one individual with prostate cancer was African American, two were of unknown race, and the remainder were Caucasian. In Newton CT 3731, all 26 individuals with prostate cancer were Caucasian.

*2. Age Distribution*

Prostate cancer incidence increases with age and is primarily a disease among men in older age groups (i.e., above 65 years) (ACS 1996; NCI 1996). In fact, more than 70% of all prostate cancers are diagnosed in men over age 65 (ACS 2001). Watertown and adjacent census tracts experienced a similar age pattern among individuals diagnosed with prostate cancer. Overall, 293 reported cases of prostate cancer were diagnosed in Watertown men during 1982-1994, and 245 of these (84%) were over the age of 65. Similar trends were observed in smaller geographic areas within Watertown (i.e., CTs 3701 and 3702). The statistically significant elevations in prostate cancer incidence in CTs 3701 and 3702 during the period 1987-1994 cannot be attributed to an increase among individuals in any one age group as elevations were observed among age groups 45-64, 65-74, 75-84, and 85+ for both census tracts.

*3. Smoking Status*

Epidemiologic studies analyzing a possible association between cigarette smoking and prostate cancer are not conclusive, although some show a positive relationship (Ross and Schottenfeld 1996). Approximately 43% of Watertown residents diagnosed with prostate cancer during 1982-1994 were current or former smokers, which is comparable to the percentage of individuals with prostate cancer in the state (40%) (see Figure 3B). Of the individuals in Watertown with known smoking status, 55% were current or former smokers at the time of diagnosis. In the Brighton/Allston census tracts evaluated in this report, approximately 52% of individuals with prostate cancer were current or former smokers. The percentage of individuals with prostate cancer in Brighton/Allston census tracts who were smokers was approximately 12% higher than in the state as a whole (see Figure 3C). Smoking status was unknown for 24% of the cases. In this area, approximately 68% of individuals with known smoking status were current or former smokers. In Cambridge CTs 3542 and 3543, 41% of individuals with prostate cancer reported themselves as current or former smokers. Smoking status was unknown for 30% of cases. Of those with known smoking status, 58% were current or former smokers. Finally, in Newton CT 3731, 46% of cases were diagnosed among current or former smokers. Smoking status was unknown for 27% of cases. Approximately 63% of

individuals with known smoking status reported being a current or former smoker at the time of diagnosis.

*4. Occupation*

An increased risk of prostate cancer has been consistently reported for employees of rubber companies, but no specific exposure related to the increase has been identified (Schottenfeld and Ross 1996). Other occupations that may be related to an increased risk of developing prostate cancer include welding, electroplating, and alkaline battery production. Exposure to cadmium as a result of working in these occupations has been suggested to be associated with the increase in prostate cancer among these workers, however, several subsequent studies have been unable to confirm this possible association. Further, it is thought that if occupation is associated with this cancer type, it is likely responsible for a very small proportion of all prostate cancer cases (Ross and Schottenfeld 1996). Review of occupational data for prostate cancer cases in Watertown and adjacent census tracts did not indicate many jobs that may be related to an increased risk of this disease. Out of a total of 469 individuals diagnosed with prostate cancer in this area, five individuals worked for a tire company, five were electrical workers, and three were welders (approximately 3% of all cases). However, as previously discussed, occupational data from MCR are often limited and 40% of individuals were reported to the MCR with "unknown" or "retired" as occupations. Therefore, it could not be determined with certainty whether occupation may have played a role in the development of prostate cancer among these individuals.

## C. Stomach Cancer

An estimated 21,700 new cases of stomach cancer will be diagnosed in the U.S. in 2001 and approximately 12,800 individuals will die of the disease (ACS 2001). Specific risk factors for this cancer include gender, race, and age. A diet high in nitrates and pre-existing medical conditions such as gastric ulcers and chronic gastritis are associated with the development of stomach cancer. Tobacco use and certain occupational exposures are also possible risk factors.

*1. Gender/Race Distribution*

Stomach cancer is twice as common among men as women, and incidence tends to be higher among Hispanics, African Americans, and Asian Americans (Nomura 1996). With the exception of Watertown CT 3704, the incidence of stomach cancer occurred approximately at or near the expected rates in Watertown and surrounding census tracts in Brighton/Allston, Cambridge, and Newton. In Watertown CT 3704, the incidence of stomach cancer was approximately twice the expected rate (13 cases observed vs. 6.4 expected, SIR=204), a statistically significant result. With the exception of one individual for whom race was unknown, all of the individuals diagnosed with stomach cancer in CT 3704 were Caucasian.

The incidence of stomach cancer exhibited no specific pattern with regard to gender in census tracts in Brighton/Allston, Cambridge, and Newton. In Brighton/Allston CTs 1.00 and 2.01, stomach cancer occurred more often than expected for males and less often than expected for females. In Brighton/Allston CT 2.02, stomach cancer occurred about as often as expected for females and more often than expected for males while in CT 3.00, the incidence was approximately at the expected rate for males but higher than expected for females. In Cambridge CTs 3542 and 3543, stomach cancer occurred less often than expected for both males and females. Finally, in Newton CT 3731, the incidence of stomach cancer was higher than expected for both genders but females experienced more than twice the number of cases expected based on state rates. With the exception of one individual for whom race was unknown and one individual with reported race as "other," all individuals diagnosed with stomach cancer in Watertown were Caucasian. In Brighton/Allston, two individuals diagnosed with stomach cancer were Chinese, one was Hispanic, one was unknown, and the remainder of the individuals were Caucasian. In Cambridge and Newton, the majority of individuals with stomach cancer were Caucasian. Although stomach cancer is twice as common among Hispanics, African Americans, and Asian Americans, the racial distribution of individuals with this cancer type in Watertown and the adjacent census tracts in Brighton/Allston, Cambridge, and Newton reflects the relatively large Caucasian population in these areas.

*2. Age Distribution*

The incidence of stomach cancer increases with age and rises sharply after the age of 60 (Nomura 1996). Although stomach cancer incidence was generally higher for older age groups in Watertown and adjacent census tracts, no specific pattern of disease with regard to age emerged upon analysis of cases. In Watertown CT 3704, a statistically significant elevation was observed in stomach cancer overall. The increase in the incidence of stomach cancer in this CT cannot be attributed to an increase in any one age group, as all age groups experienced elevations. In Watertown as a whole, 38 of the 56 cases were 65 years or older (68%) and in CT 3704, 10 of the 13 cases were 65 years or older (77%), which is consistent with the age pattern observed in the general population.

*3. Smoking Status*

The association between stomach cancer and cigarette smoking is unclear. However, several studies have found that heavy smokers have an increased risk of developing stomach cancer, especially smokers who routinely swallow cigarette smoke (Nomura 1996). Furthermore, both mainstream and sidestream tobacco smoke contains N-nitroso compounds, suspected carcinogens in the development of stomach cancer.

In Watertown, 48% of individuals diagnosed with stomach cancer reported themselves as current or former smokers. This compares to about 44% of stomach cancer cases in Massachusetts. Smoking status was unknown for 27% and 23% of individuals diagnosed with stomach cancer in Watertown and Massachusetts, respectively (see Figure 3D). In Watertown, of those individuals diagnosed with stomach cancer whose smoking status was known, 66% reported being current or former smokers at the time of diagnosis. In the Brighton/Allston census tracts evaluated, approximately 46% of individuals diagnosed with stomach cancer were current or former smokers at the time of their diagnosis. Smoking status was unknown for 29% of individuals. Of those with known smoking status, 65% were current or former smokers. In Cambridge CTs 3542 and 3543, smoking status was known for all 7 cases and 29% were current or former smokers. In Newton CT 3731, 30% of individuals reported themselves as current or

former smokers. Smoking status was unknown for 20% of individuals. Of those with known smoking status, 38% were current or former smokers at the time of diagnosis.

*4. Occupation*

Available evidence indicates that occupational exposures do not play a major role in the incidence of stomach cancer. It is suspected that coal miners and asbestos workers are at increased risk for developing stomach cancer, however, this evidence is inconclusive. Other occupations possibly associated with stomach cancer include workers in the chemical, rubber, oil refinery, metal-products industries, and other industries involving mineral dust exposure. Suspected carcinogenic agents include asbestos, polycyclic aromatic hydrocarbons, and N-nitroso compounds (reviewed in Nomura 1996). Occupational data on 97 individual cases of stomach cancer in Watertown and adjacent census tracts in Brighton/Allston, Cambridge, and Newton was reviewed. Although the analysis did not indicate any jobs that might be associated with an increased risk of stomach cancer, except for one individual in Brighton/Allston and one individual in Watertown, much of the occupational data were incomplete. For approximately half the cases, occupation was listed as "retired," "housewife," "at home," or "unknown." Therefore, it could not be determined with certainty if occupation may have played a role in the incidence of stomach cancer in this community.

## D. Thyroid Cancer

The thyroid is one of the least cancer-prone organs in the body, representing only 0.54% cancers occurring among men in the U.S. and 1.7% among U.S. females (Ron 1996). It is, however, one of the most common neoplasms in adolescents and young adults. Thyroid cancer is primarily associated with external x-ray treatments of benign medical conditions in childhood or external radiation (e.g., from atomic bomb fallout exposures). Gender, race, and age also play roles in the development of this disease.

*1. Gender/Race Distribution*

The female to male ratio of thyroid cancer is high after puberty and during the reproductive years, then declines at the time of menopause. Thus it is of note that the

thyroid gland becomes enlarged during puberty and pregnancy and may change in size and activity during the menstrual cycle (Robbins et al. 1984). In addition, the incidence of thyroid cancer is about two times greater among whites than among blacks and persons of Asian origin have elevated rates compared to persons of other ethnic backgrounds living in the same areas (Ron 1996).

The incidence of thyroid cancer in Watertown and adjacent census tracts is consistent with the reported pattern of this disease. In general, more cases of thyroid cancer occurred among females than among males across all areas evaluated. Again, the majority of individuals diagnosed with thyroid cancer in these areas were Caucasian.

*2. Age Distribution*

Although the incidence of thyroid cancer increases with increasing age, it is comparatively slower than most other cancer types and is a cancer predominantly diagnosed among individuals between the ages of 15 and 39. In this age group, thyroid cancer accounts for 8.7% of all newly diagnosed cancers, as compared to 0.7% between the ages of 55 and 64, and 0.3% at age 80 and above. In fact, thyroid cancer was ranked as one of the five most frequent cancers among persons aged 15-39 (Ron 1996).

In Watertown, 54% of the diagnosed cases were between the ages of 15-39. Review of age group specific SIRs revealed that the highest rates of thyroid cancer for Watertown and surrounding areas during 1982-1994 occurred in the 0-19 and 20-44 age groups as expected based on available evidence regarding the age pattern of this disease.

*3. Smoking Status/Occupation*

Smoking has not been shown to be a risk factor in the development of thyroid cancer (ACS 1999). Further, the available literature indicates that occupational exposures also do not play a major role in the incidence of thyroid cancer (Ron 1996).

## VII. Evaluation of Geographic Distribution

Place of residence at the time of diagnosis was geocoded and mapped for each of the four cancer types to assess any possible geographic pattern of cases. In addition to

quantitatively determining census tract-specific incidence ratios for each cancer type, a qualitative evaluation was conducted to determine whether any specific cancer type appeared to be concentrated in some area(s) within Watertown or adjacent census tracts. Figure 2 depicts the locations of these census tracts within their respective towns and in relation to the AMTL site.

## A. Watertown

Review of data for NHL for Watertown showed that the distribution of cases throughout individual and adjacent census tracts does not present any specific geographic pattern. In general, the geographic pattern of cancer cases in Watertown during 1982-1994 showed a distribution of cases that is consistent with the population density of the town. However, there appeared to be a small concentration of NHL cases in Watertown CT 3703 (not near the AMTL site) and stomach cancer cases in CT 3704 in a neighborhood bordering the AMTL site. For confidentiality reasons, MDPH cannot reveal the exact location of these cases.

As noted earlier, in January 2000, MDPH released a report on a follow-up evaluation of risk factor information and residential histories for certain cancer types that appeared concentrated in Watertown based on findings from the original health consultation (ATSDR 1996, 2000). Included in this investigation were four individuals diagnosed with NHL in CT 3703 and four individuals diagnosed with stomach cancer in CT 3704 whose residences at the time of diagnosis (between 1982 and 1990) were located near one another. Based on residential histories, available risk factor information (e.g., age, smoking status, occupation), and known environmental risk factors associated with these cancers, MDPH concluded that the occurrence of NHL and stomach cancer among these groups of individuals did not suggest any single factor (environmental or non-environmental) that might explain the distribution of cancer in these areas of Watertown.

The apparent concentrations of NHL and stomach cancer found upon review of individuals diagnosed between 1982 and 1994 represent the same areas identified in the 1996 health consultation, with one additional individual diagnosed with cancer in each

group. Residential histories were conducted for each of these ten individuals using town residential lists (Town of Watertown, 1964-1994). Review of this information revealed that of the five individuals diagnosed with NHL who lived near each other in CT 3703, four had lived at their address for greater than or equal to 20 years at the time of diagnosis and one had lived at their address for at least three years prior to diagnosis. Of the five individuals diagnosed with stomach cancer in CT 3704, three had lived at their address for greater than or equal to 20 years at the time of diagnosis, two had lived at their address for at least 12 years, and one had lived at their address at least 11 years prior to diagnosis. Based on available risk factor information for these individuals, it does not appear that these individuals share a single common risk factor (environmental or otherwise) other than place of residence.

### B. Brighton/Allston, Cambridge, and Newton

Review of the geographic distribution for the four cancer types evaluated revealed no apparent spatial patterns for any specific cancer type in Brighton/Allston CTs 1.00, 2.01, 2.02, and 3.00. Although a statistically significant elevation in the incidence of NHL among males was observed in CT 1.00 during the later time period 1987-1994 (7 cases observed vs. 2.4), the geographic distribution of cases did not appear concentrated in any one area of this census tract.

Review of the geographic distribution for the four cancer types evaluated revealed no apparent spatial patterns for any specific cancer type in Cambridge CTs 3742 and 3743 or Newton CT 3731.

## VIII. COMMUNITY ENVIRONMENTAL CONCERNS

As noted above, this analysis was prompted by a request from the Watertown AMTL RAB based on community concerns about the possibility of a relationship between cancer incidence and environmental exposures at a National Priority List (NPL) site in Watertown (e.g., AMTL). In 1997, as required by law for all sites on the EPA National Priorities List, ATSDR released a public health assessment for the AMTL site (ATSDR 1997). The public health assessment evaluated whether chemical contaminants

disposed or released into the environment at AMTL and other former Watertown Arsenal properties have the potential to cause adverse health effects. Three exposure pathways were identified in the public health assessment: subsurface soil contamination, fish contamination in the Charles River, and past air releases of depleted uranium. In the case of subsurface soil contamination, ATSDR concluded that the general public is not likely to be exposed to or come into contact with residual contamination at the site. ATSDR noted that results of fish sampling prompted the MDPH to issue a fish consumption advisory for this area of the Charles River due to high levels of PCBs in carp. If this advisory is followed, exposure to contaminants in fish from the Charles River poses no apparent public health hazard. Finally, depleted uranium was burned at the Watertown Arsenal in the past. However, ATSDR concluded that possible exposure to airborne contaminants was below levels of health concern for the few residents living close enough to the Arsenal to have been exposed in the past. ATSDR also noted that future land use of the AMTL site poses no public health hazard because before the land can be transferred for reuse, all necessary cleanup actions must be completed.

Although contaminants were found in groundwater and subsurface soils at the AMTL site, ATSDR concluded that it is unlikely that residents could be exposed to significant concentrations of contaminants that would have the potential to produce adverse health effects in areas surrounding the former Arsenal site. ATSDR calculated cancer risk estimates related to radiation dose for individuals possibly exposed to airborne depleted uranium and found that the lifetime cancer risk was approximately 10 times less than the risk of cancer expected from background radiation levels (e.g., natural radiation in the environment). In addition, ATSDR noted that lung cancer would comprise virtually all the risk from this potential exposure. In an initial health consultation for Watertown, review of lung cancer incidence in Watertown or its census tracts did not indicate elevations in this cancer type or geographic patterns that would suggest a relationship to the AMTL site (ATSDR 1996). Further, the most recent data available from the MCR for the time period 1994-1998 show that lung cancer incidence in Watertown as a whole was lower than expected (MDPH 2001).

## IX. DISCUSSION

In the majority of the eleven census tracts evaluated in Watertown, Brighton/Allston, Cambridge, and Newton, NHL, prostate cancer, stomach cancer, and thyroid cancer occurred approximately at or near the expected rates based on statewide incidence during 1982-1994. Some statistically significant elevations, however, were noted. Statistically significant elevations were noted for NHL in Watertown as a whole and in CT 3704, as well as for Brighton/Allston CT 1.00 (for males only) during one or more time periods. Watertown as a whole and CTs 3701 and 3702 displayed statistically significant elevations of prostate cancer in one or more time periods evaluated. Stomach cancer was statistically significantly elevated in Watertown CT 3704 during the overall time period 1982-1994. While some other elevations were noted in the incidence of these cancer types in certain census tracts, these were primarily based on small numbers of cases and were not statistically significant. Analysis of the statistically significant elevations generally revealed no consistent trends of cancer incidence at the census tract level or in relation to the AMTL site throughout the 13-year time period evaluated. In addition, the census tracts with statistically significant elevations in cancer incidence were generally not adjacent to each other.

Analysis of more recent data (e.g., for the years 1994-1998) revealed that incidence rates for prostate cancer have remained statistically significantly elevated in Watertown as whole. Elevations were also noted for NHL and thyroid cancer, however, these elevations were not statistically significant.

The evaluation of the geographic distribution of the four cancer types for the years 1982-1994 revealed that two areas identified in the 1996 consultation still appeared to have some concentration of cases (i.e., NHL in CT 3703 and stomach cancer in CT 3704). No other area in all census tracts evaluated appeared to have any unusual concentration of cases within the census tract. MDPH further evaluated the NHL and stomach cancer cases that appeared concentrated. Results indicated that based on residential histories and known risk factor information, it does not appear that any single cause, environmental or otherwise, is likely to explain the occurrence of all of these cases. In addition, based on the information reviewed in this analysis related to risk

factors for development of these cancers (e.g., age, gender, smoking, and occupation), this analysis did not reveal any pattern or trend that was unexpected or inconsistent with established incidence patterns for these cancer types. It is likely that smoking played a role in the incidence of NHL, prostate cancer, and stomach cancer in Watertown and surrounding communities. However, due to the number of individuals for whom smoking status was unknown, the extent of this role is not clear. Therefore, it appears unlikely that a single factor, including environmental factors, was primarily responsible for the observed pattern of cancer incidence in the Watertown area. As discussed below, a number of factors or combination of factors which were not able to be evaluated in this report may influence the development of the cancer types evaluated in this investigation.

## A. Non-Hodgkin's Lymphoma

Overall, between 1973 and 1997, the incidence of NHL in the U.S. grew 81% (Garber 2001). This increase has been attributed to better diagnosis, greater exposure to causative agents, and, to a lesser extent, the increasing incidence of AIDS-related lymphomas (Devesa and Fears 1992; Scherr and Mueller 1996). Although primary factors related to the development of NHL include conditions that relate to the suppression of the immune system, viral infections, and certain occupational exposures, these factors are thought to account for only a portion of the increase observed in this cancer type (Scherr and Mueller 1996).

NHL is more common among people who have abnormal or compromised immune systems, such as those with inherited diseases that suppress the immune system, organ transplant recipients, and individuals with autoimmune disorders (Scherr and Mueller 1996). NHL has also been reported to occur more frequently among individuals with conditions that require medical treatment resulting in suppression of the immune system, such as cancer chemotherapy. However, current evidence suggests that the development of NHL is related to suppression of the individual's immune system as a result of treatment rather than the treatment itself (Scherr and Mueller 1996).

Several viruses have been shown to play a role in the development of NHL. Among organ transplant recipients, suppression of the immune system required for

acceptance of the transplant leads to a loss of control or the reactivation of viruses that have been dormant in the body (e.g., Epstein-Barr Virus [EBV] and herpesvirus infections). In addition, because cancer-causing viruses are known to cause lymphomas in various animals, it has been proposed that these types of viruses may also be associated with the development of NHL among humans without compromised immune systems. Infection with the human T-cell leukemia/lymphoma virus (HTLV-I) is known to cause T-cell lymphoma among adults. However, this is a relatively rare infection and most likely contributes only a small amount to the total incidence of NHL (Scherr and Mueller, 1996). EBV infection is common among the general population and has been shown to play a role in the development of most cases of transplant and AIDS related NHL. The combination of immune system deficiencies and EBV infection may cause some people to develop NHL (ACS, 1998). Although viruses are causal factors for some subtypes of NHL, to date, studies have shown that the role of EBV in the development of NHL in the general population may not be large (Scherr and Mueller, 1996). Moreover, the high prevalence of EBV in the general population suggests that EBV may be only one of several factors in the development of this cancer.

As noted above, herbicides and insecticides have been linked to an increased risk for NHL among agricultural workers. Recent studies have suggested that contamination of drinking water with nitrate may be associated with an increased risk of NHL (Ward et al. 1996). Nitrate forms N-nitroso compounds, which are known carcinogens and can be found in tobacco, smoked or salt-dried fish, bacon, sausages, other cured meats, beer, pickled vegetables, and mushrooms.

Although NHL is associated with a number of risk factors, the causes of this disease remain unknown. Further, most patients with NHL do not have any known risk factors (ACS 1998).

Based on the data evaluated, a statistically significant elevation in the incidence NHL was observed for the town of Watertown as a whole for 1982-1994 (SIR=129) and in CT 3704 (SIR=197), adjacent to the AMTL site. Census tracts 3701 and 3702 also displayed elevated but not statistically significant rates of NHL. Therefore, the significant

elevation in CT 3704 alone does not appear to explain the increased incidence of NHL in the town of Watertown. In CT 3703, which surrounds most of the AMTL site, the incidence rate of NHL was as expected. During 1994-1998, NHL for Watertown as a whole was still elevated but no longer statistically significantly elevated. In regards to the potential risk of NHL when exposed to nitrates in drinking water, it should be noted that groundwater at the AMTL site was not found to be contaminated with nitrates. Further, exposure by the general public to contaminated groundwater is not likely because the water in this area is not used for domestic purposes (ATSDR 1997). The municipal drinking water within 4 miles of the site is supplied by surface water sources located to the west of AMTL and is unaffected by the site (EPA 2001). The municipal drinking water is routinely tested for contaminants, including nitrate. Nitrate levels in the Watertown drinking water supply have consistently been below EPA's Maximum Contaminant Levels (MWRA 2001). Some studies have suggested that environmental (i.e., chemical) exposures may be related to the development of NHL, however, no definitive association has been established.

In Brighton/Allston CT 1.00, located across the Charles River from the AMTL site, a statistically significant increase in NHL among males was observed during the 1987-1994 time period. However, review of information on residence at diagnosis revealed that cases were widely scattered with the census tract. There were no NHL cases observed among females in Brighton/Allston CT 1.00 for any of the time periods evaluated. Incidence of NHL was approximately at or near expected rates for all other census tracts evaluated in Watertown, Brighton/Allston, Cambridge, and Newton.

## B. Prostate Cancer

Prostate cancer rates are greater in countries where the population consumes more animal fat (Devesa et al. 1995; NCI 1996; Schottenfeld and Ross 1996). Prostate growth depends on the hormone testosterone and some studies have suggested that a diet high in animal fats also increases the levels of this hormone, which may elevate the risk for prostate cancer. In several large cohort and case-control studies, overweight men (defined as >30% above ideal body weight) had approximately 2.5 to 4.4 times the risk of

developing prostate cancer than men who were near their desirable weight (Schottenfeld and Ross 1996).

Additional risk factors for prostate cancer include a higher prevalence of past venereal disease, as shown in several large epidemiological studies (Schottenfeld and Ross 1996). Available epidemiological data strongly support a familial tendency toward prostate cancer occurrence.

Increasing prostate cancer incidence appears related to changes in diagnostic methods, such as serum testing for prostate-specific antigen PSA, which has led to increased detection at earlier stages (ACS 1996; Devesa et al. 1995; NCI 1996). By the late 1980s, prostate cancer became the most commonly diagnosed malignancy among U.S. men (Devesa et al. 1995).

Prostate cancer was statistically significantly elevated among males in the town of Watertown, particularly during the later portion of the 13 years evaluated (i.e., 1987-1994). Prostate cancer remained statistically significantly elevated townwide during 1994-1998. The townwide elevation from 1982-1994 was largely a result of statistically significant elevations that occurred among males in CT 3701 during the 1987-1994 time period and CT 3702 during the 1982-1994 time period. These census tracts are located in the northwest area of Watertown and are not near the AMTL site. The incidence of prostate cancer was approximately at or near expected rates for all other census tracts evaluated in Watertown, Brighton/Allston, Cambridge, and Newton. Review of demographic information for prostate cancer cases revealed that 81% of cases were over the age of 65, a pattern consistent with the available literature on the disease. In addition, review of the annual distribution of prostate cancer diagnoses in Watertown suggests that the observed elevation in incidence could be attributed to an increase in the number of individuals diagnosed with this cancer type in the early 1990s. The incidence of prostate cancer increased sharply over time in Massachusetts from 1982 to 1992. The same pattern was seen nationally and is primarily attributed to increased use of the PSA screening test in the late 1980s and early 1990s (MDPH 2000). The pattern of prostate cancer incidence in Watertown follows this trend and may be related to an increase in

screening and early detection of this cancer. Analysis of the geographic distribution of prostate cancer cases and the fact that environmental risk factors are not associated with prostate cancer suggests that it is unlikely that the increased incidence of prostate cancer observed in Watertown is related to the AMTL site.

### C. Stomach Cancer

The rate of stomach cancer incidence is higher among persons in lower socioeconomic classes and for those who live in colder climates (ACS 1996; Nomura 1996). In the United States, studies have shown high rates of this cancer in urban areas of the northeast (Nomura 1996).

The relationship between diet and stomach cancer has been extensively researched. A series of studies has linked the intake of nitrates and related compounds to stomach cancer (NCI 1996; Nomura 1996). Sources of dietary nitrate include drinking water, green vegetables, cured meats, some cheeses, and other foods. Nitrate forms N-nitroso compounds, which are potent carcinogens and can be found in smoked or salt-dried fish, bacon, sausages, other cured meats, beer, pickled vegetables, and mushrooms.

Several medical conditions are also associated with a higher risk of developing stomach cancer including gastric ulcers, gastric polyps, chronic gastritis, intestinal metaplasia, and gastroenterostomy (Nomura 1996). Infection with Helicobacter pylori, believed to be a common cause of gastritis and peptic ulcers, plays a role in the initiation of precancerous stomach changes (NCI 1996). Pernicious anemia also changes the stomach lining and may be related to increased risk for stomach cancer (NCI 1996). Radiation may also increase the risk of stomach cancer as seen in atomic bomb survivors and studies of patients treated with X-rays for a spinal disorder (NCI 1996; Nomura 1996). In addition, family studies have suggested a possible genetic susceptibility (NCI 1996; Nomura 1996).

With the exception of a statistically significant elevation in CT 3704 (SIR=204) and a non-significant elevation in Newton CT 3731, the incidence of stomach cancer was approximately at or near the expected rates in the town of Watertown and adjacent census

tracts in Brighton/Allston, Cambridge, and Newton. Although recent evidence links nitrates to stomach cancer, nitrates were not found in groundwater at the AMTL site. Further, the groundwater at the site is not used for domestic purposes. The municipal drinking water is routinely tested for contaminants, including nitrate. Nitrate levels in the Watertown drinking water supply have consistently been below EPA's Maximum Contaminant Levels (MWRA 2001). Because there are no established environmental risk factors for stomach cancer, it is not likely that the observed increases in the incidence of stomach cancer in Watertown or Newton CT 3731 are related to contamination at the AMTL site.

## D. Thyroid Cancer

Thyroid cancer is primarily associated with external (e.g., head and neck) x-ray treatments of benign medical conditions in childhood (ACS 1996; Amdur et al. 1991; BEIR 1990; EPA 1989). Whole-body external radiation such as gamma radiation, as in the case of atomic bomb survivors, has been associated with the development of this cancer (BEIR 1988; Lundell et al. 1994; Ron et al. 1995). An analysis of data from the Marshall Islands on radioactive fallout exposures has also shown an association between radiation exposures and elevated thyroid cancer incidence (BEIR 1990). Therapeutic use of radioactive iodine (primarily for treatment of thyrotoxicosis) does not appear to be associated with an increase in thyroid cancer risk (ACS 1996; BEIR 1990; Higginson et al. 1992). Additional risk factors for thyroid cancer are non-malignant thyroid disorders and a positive family history of these disorders (Higginson et al. 1992).

Thyroid cancer occurred approximately at or near the expected rates in the town of Watertown and adjacent census tracts in Brighton/Allston, Cambridge, and Newton. Although not statistically significant, thyroid cancer occurred about twice as often as expected in Watertown CT 3703 (7 cases observed vs. 3.6 cases expected), which borders the AMTL site. The development of thyroid cancer has been associated with exposure to radiation as a result of radioactive fallout from nuclear weapons or power plant accidents. However, the type of radiation associated with depleted uranium (alpha emitter) has not been linked to thyroid cancer. In addition, ATSDR concluded that radiation at the AMTL

site from the burning of depleted uranium was below levels of health concern and that radiation dose estimates that could have resulted if exposure had occurred to Watertown residents in the past showed a lifetime cancer risk less than expected from naturally occurring radiation. No other environmental factors have been shown to be positively associated with the development of thyroid cancer. Therefore, it is unlikely that the elevated incidence of thyroid cancer in CT 3703 is associated with contamination at the AMTL site.

## X. CONCLUSIONS

This analysis is descriptive in nature and can only provide an evaluation of cancer incidence in Watertown and adjacent census tracts in comparison to cancer incidence in the state. Cancers in general have a variety of associated risk factors that are likely related to the etiology (development) of disease. Many cancers are believed to be related largely to lifestyle factors such as cigarette smoking, diet, and alcohol consumption. Epidemiologic studies of humans and laboratory animals have related several cancers to chemical exposures in the workplace or in an individual's environment. Other factors associated with cancer are socioeconomic status, heredity/genetics, age, race, and geography.

Watertown experienced statistically significant elevations in NHL and prostate cancer during 1982-1994. Review of 1994-1998 data shoed that prostate cancer remained statistically significantly elevated townwide and that NHL was elevated but no longer statistically significant. In CT 3703, which surrounds most of the AMTL, there were no statistically significant elevations for the four cancer types evaluated. In this census tract, NHL, prostate cancer, and stomach cancer occurred below the expected rate, while thyroid cancer occurred more often than expected (about three or four excess cases). In CT 3704, NHL and stomach cancer were statistically significantly elevated during one or more time periods evaluated. However, review of the geographic distribution and available risk factor and residential history (for stomach cancer only) information did not suggest that any single factor, environmental or otherwise, likely played a primary role in the occurrence of these cases. Incidence rates for prostate and thyroid cancers were slightly elevated but these

elevations were not statistically significant and there were no geographic concentrations of cases within the census tract.

In general, for all four cancer types evaluated in Watertown and surrounding areas, the ages at diagnosis and risk factor information were consistent with what the medical literature has described regarding the occurrence of these diseases and risk factors in the general population and did not appear to be atypical. Therefore, the pattern of cancer incidence for these four cancer types as well as other information evaluated in this report (e.g., geographic distribution) suggests that it is unlikely that contaminants at the AMTL site played a primary role in the observed pattern of these cancer types in Watertown and surrounding areas. However, it is beyond the scope of this investigation to determine any causal relationship or synergistic roles that risk factors discussed in this report may have played in the development of cancer for individuals in the Watertown AMTL study region.

## XI. RECOMMENDATIONS

MDPH recommends that the Watertown Board of Health consider additional efforts to educate residents about risk factors related to the development of these cancers, particularly prostate and stomach cancers. Special emphasis should be placed on behavioral risk factors, such as cigarette smoking, diet, and exercise. The BEHA will forward the results of this evaluation to the MDPH Bureau of Family and Community Health (BFCH) for consideration of future cancer control activities in Watertown.

Through the use of the Massachusetts Cancer Registry, MDPH will continue to monitor the incidence of NHL, prostate cancer, stomach cancer, and thyroid cancer in Watertown.

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# Figures

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