Assessment of Cancer Incidence in Weymouth, Abington, Hingham, and Rockland, MA 1995-1998

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I. INTRODUCTION

This appendix serves as a follow-up to the evaluation of cancer incidence conducted in the four towns Weymouth, Abington, Hingham, and Rockland for the time period 1982-1994. As previously noted, the initial evaluation was conducted based on concerns over possible exposures from environmental contamination present at the South Weymouth Naval Air Station (SWNAS). The initial evaluation provides a descriptive analysis of cancer incidence data from the Massachusetts Cancer Registry (MCR) for the time period 1982-1994. Since the initiation of this investigation, more recent data (e.g., for the years 1995-1998) have become available from the MCR. Therefore, this follow-up reviews cancer incidence in the towns of Weymouth, Abington, Hingham, and Rockland at the town level and for the census tracts that geographically subdivide the towns for the time period 1995-1998. Particular emphasis was placed on those census tracts immediately surrounding the SWNAS. Refer to Figure 1 for the location of census tracts surrounding the SWNAS.

II. OBJECTIVES

This report provides a descriptive evaluation of the occurrence of cancer in the towns of Weymouth, Abington, Hingham, and Rockland during the years 1995-1998. Eight cancer types were included in this evaluation: bladder cancer, brain cancer, kidney cancer, leukemia, liver cancer, lung cancer, non-Hodgkin's lymphoma, and pancreatic cancer. These cancer types were selected for evaluation based on results of a previous review of cancer rates in Weymouth, Abington, Hingham, and Rockland as well as community concerns over suspected elevations in the incidence of specific cancer types (MDPH 1996). The investigation provides a comparison of the incidence of the selected cancer types in these communities with the incidence of cancer in the state of Massachusetts as a whole. The state of Massachusetts is used as a comparison to provide a stable, standard population to calculate and compare cancer incidence rates. Additionally, available information about risk factors (including environmental factors) related to the development of cancer was evaluated.

This descriptive analysis of cancer incidence data cannot be used to establish a causal link between a particular risk factor and the development of cancer. In addition, this analysis

cannot determine the cause of any one individual's cancer diagnosis. However, the results can be useful in identifying patterns or trends in a geographic context, to determine if a common cause or etiology is possible, and can serve to identify areas where further public health investigations or actions may be warranted. Descriptive analyses may also indicate that an excess of known risk factors associated with a disease, such as environmental exposures, exists in a certain geographic area. The purpose of this evaluation is to report the findings on patterns of cancer in these communities and discuss them in the context of the available information to determine whether recommendations for further public health action are warranted.

The specific objectives of this investigation were as follows:

- To further evaluate the incidence of cancer in Weymouth, Abington, Hingham, and Rockland by smaller geographic areas within the towns (i.e., census tracts) to determine if certain areas have higher or lower cancer rates, in particular the census tracts surrounding the SWNAS;

- To evaluate the geographic distribution of cancer in Weymouth, Abington, Hingham, and Rockland by mapping individual cases to determine whether any indication of a pattern of cases exists in certain areas of the town, in relation to the SWNAS, or in relation to other areas of environmental concern in Weymouth, Abington, Hingham, and Rockland;

- To review available descriptive information related to risk factors as reported by the MCR for individuals diagnosed with cancer in Weymouth, Abington, Hingham, and Rockland; and

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

III. METHODS

A. Case Identification/Definition

Cancer incidence data (i.e., new cancer diagnoses) for 1995-1998 were obtained for the towns of Weymouth, Abington, Hingham, and Rockland from the MCR of the MDPH. Only cases reported to the MCR as a primary cancer diagnosed among a resident of these towns were included. Cases were selected for inclusion based on the address reported to the hospital or reporting medical facility at the time of diagnosis.

In this report, the observed case count for a particular type of cancer is the actual number of newly diagnosed cases reported to have been diagnosed in residents of Massachusetts from 1995-1998. The "total" observed case count for each cancer type is the sum of the number of observed male and female cases only. The MCR added two additional gender classifications (transsexuals and persons with sex chromosome abnormalities/hermaphrodites) for cases diagnosed as of January 1, 1995. (Cases diagnosed before this date were limited to male or female only.) Any case classified in either of the new gender categories is not included in this report because the population data used in the statistical calculations only include male and female categories. During 1995-1998, no cases of the eight cancer types evaluated in this report in Weymouth, Abington, Hingham, or Rockland were classified in either of the new gender categories.

The MCR is a population based surveillance system that 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). The 17-year period 1982-1998 constitutes the period for which the most recent and complete cancer incidence data were available from the MCR at the time of this analysis.

The term "cancer" is used to describe a variety of diseases associated with abnormal cell and tissue growth. Epidemiologic studies have revealed that different types of cancer are individual diseases with separate causes, risk factors, characteristics and patterns of survival (Berg 1996). Cancers are classified by the location in the body where the disease originated (the

primary site) and the tissue or cell type of the cancer (histology). Therefore, each of the cancer types reviewed in this report was evaluated separately. Cancers that occur as the result of the metastasis or the spread of a primary site cancer to another location in the body are not considered as separate cancers and therefore were not included in this analysis.

Eight primary cancer types were evaluated in this investigation; they are bladder cancer, brain cancer, kidney cancer, leukemia, liver cancer, lung cancer, non-Hodgkin's lymphoma, and pancreatic cancer. It should be noted that the MCR collects data on cancerous and some non-cancerous tumors of the brain and central nervous system as one group. This report reflects only those tumors that occurred in the brain.

In addition, the MCR data file may occasionally contain duplicate reports of cases. The data discussed in this report have been controlled for duplicate cases by excluding them from the analyses. However, reports of an individual with multiple primary cancers were included. Duplicate cases are additional reports of the same primary site cancer. A multiple primary cancer case is defined by the MCR as a report of a new tumor in a different primary site, or a new tumor of the same histology (cell type) as an earlier cancer, if diagnosed in the same location in the body more than two months after the initial diagnosis (MCR 1996). Therefore, duplicate reports of an individual diagnosed with cancer were removed from the analyses whereas individuals who were diagnosed with more than one primary site cancer were included as separate cases. The decision that a case was a duplicate report and should be excluded from the analyses was made by the MCR after consulting with the hospital or reporting facilities and obtaining additional information regarding the histology and/or pathology of the case. In the towns of Weymouth, Abington, Hingham, and Rockland, two duplicate reports were identified and excluded from the analysis.

B. Calculation of Standardized Incidence Ratios (SIRs)

To determine whether elevated numbers of cancer cases occurred in the four towns or their census tracts, cancer incidence data were tabulated by age group and gender to compare the observed number of cancer cases to the number that would be expected based on the statewide cancer rate. Standardized incidence ratios (SIRs) were calculated for the period 1995-1998 for

each of the eight primary cancer types for each town as a whole and the census tracts (CTs) within each town.

In order to calculate standardized incidence ratios, it is necessary to obtain accurate population information. The population figures used in this analysis were interpolated based on 1990 and 2000 U.S. census data for each CT in Weymouth, Abington, Hingham, and Rockland (U.S. DOC. 1990, 2000). Midpoint population estimates were calculated for the 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. In this report, 1996 was used as the midpoint for the period 1995-1998.

Because accurate age group and gender specific population data are required to calculate SIRs, the CT is the smallest geographic area for which cancer rates can be accurately calculated. Specifically, a CT is a smaller statistical subdivision of a county as defined by the U.S. Census Bureau. CTs usually contain between 2,500 and 8,000 persons and are designed to be homogenous with respect to population characteristics (U.S. DOC. 1990).

According to the 1980 U.S. Census, the town of Weymouth was subdivided into eight census tracts, the towns of Abington and Hingham were comprised of three census tracts, and the town of Rockland was comprised of two census tracts (U.S. DOC. 1980). During the 1990 U.S. Census, the Census Bureau further divided two Weymouth CTs (4223 and 4225), one Hingham CT (5012), and one Rockland CT (5021). The split in these census tracts produced a total of ten census tracts in Weymouth (4221, 4222, 4223.01, 4223.02, 4224, 4225.01, 4225.02, 4226, 4227, and 4228), four census tracts in Hingham (5011.01, 5011.02, 5012.01, and 50120.2), and three census tracts in Rockland (5021.01, 5021.02, and 5022). In order to evaluate cancer incidence by census tract over time, population data for the split CTs were combined for each year (e.g., 1990 and 2000) in Weymouth, Hingham, and Rockland to remain consistent with the 1980 population data and CT designations, as indicated in the initial report. The town of Abington did not experience a split among any of the three census tracts that subdivide the town. Therefore, for the purpose of this evaluation SIRs were calculated according to the 1980 census tract designations for eight Weymouth census tracts (4221, 4222, 4223, 4224, 4225, 4226, 4227, and 4228), three Abington census tracts (5201, 5202.01, and 5202.02), three Hingham census tracts

(5011.01, 5011.02, and 5012), and two Rockland census tracts (5021 and 5022). The town boundaries and census tract locations for Weymouth, Abington, Hingham, and Rockland are illustrated in Figure 1.

The SWNAS is located within three CTs in the towns of Weymouth, Abington and Rockland. These include CT 4222 in Weymouth, CT 5202.01 in Abington and CT 5022 in Rockland. CT 5012 in the southern portion of Hingham is adjacent to the SWNAS (see Figure 1).

C. Interpretation of a Standardized Incidence Ratio (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 a 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.

Specifically, an SIR is the ratio of the observed number of cancer cases in an area to the expected number of cases multiplied by 100. The population structure of each town is adjusted to the statewide incidence rate to calculate the number of expected cancer cases. The SIR reflects a comparison of the number of cases in the town compared to the statewide rate, using the specific age/sex structure of the statewide rate as the weights to determine the expected number of cases in each town. Therefore, because each community has different population characteristics, town-to-town or census tract comparisons are not possible.

An SIR of 100 indicates that the number of cancer cases observed in the population being 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 were expected and an SIR less than 100 indicates that fewer cancer cases occurred than were expected. Accordingly, an SIR of 150 is interpreted as 50% more cancer cases than the expected number; an SIR of 90 indicates 10% fewer cancer 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. As a result of the instability of incidence rates based on small numbers of cases, SIRs were not calculated when fewer than five cases were observed for a particular cancer type.

D. Calculation of the 95% Confidence Interval

To help interpret or measure the stability of an SIR, the statistical significance of each SIR was assessed by calculating a 95% confidence interval (95% CI) 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 (Rothman and Boice 1982). 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 a 5% chance that the observed difference (either increase or decrease) 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), 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), the number of cancer cases is statistically significantly lower than expected. If the confidence interval range includes 100, the true SIR may be 100. In this case, it cannot be determined with certainty that the difference between the observed and expected number of cases reflects a real cancer increase or decrease or is the result of chance. It is important to note that statistical significance does not necessarily imply public health significance. Determination of statistical significance is just one tool used to interpret SIRs.

In addition to the range of the 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. Again, due to the instability of incidence rates based on small numbers of cases, statistical significance was not assessed when fewer than five cases were observed.

E. Evaluation of Risk Factor Information

Available information reported to the MCR related to risk factors for cancer development was reviewed and compared to known or established incidence patterns for the cancer types evaluated in this report. This information is collected for each individual at the time of cancer diagnosis and includes age at diagnosis, stage of disease, smoking status and occupation. One or even several factors acting over time can be related to the development of cancer. For example, tobacco use has been linked to lung and bladder cancers. Other cancer risk factors may include lack of crude fiber in the diet, high fat consumption, alcohol abuse, and reproductive history. Heredity, or family history, is an important factor for several cancers. To a lesser extent, some occupational exposures, such as jobs involving contact with asbestos, have been shown to be carcinogenic (cancer causing). Environmental contaminants have also been associated with certain types of cancer. The available risk factor information from the MCR was evaluated for cancers that were elevated in Weymouth, Abington, Hingham, and Rockland. However, 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.

F. Determination of Geographic Distribution

Address at the time of diagnosis for each cancer case was mapped using a computerized geographic information system (GIS) (ESRI 1998). This allowed for the assignment of census tract location for each case as well as an evaluation of the spatial distribution of individual cases at a smaller geographic level within census tracts (i.e., neighborhoods). The geographic distribution was determined using a qualitative evaluation of the point pattern of cases within the towns and their individual census tracts. In instances where the address information from the MCR 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. For confidentiality reasons, maps of the location of individual cancer cases are not provided in this report.

IV. RESULTS OF CANCER INCIDENCE ANALYSIS

The following sections present cancer incidence rates for each of the four towns (Weymouth, Abington, Hingham, and Rockland) as a whole as well as for each of their census tracts during the four-year period 1995-1998. The census tract-specific analyses help in understanding whether the incidence of cancers observed townwide or region-wide may be explained by an increase or decrease in cases in a particular geographic area of the town. Tables 1 though 20 summarize cancer incidence data for Weymouth, Abington, Hingham, and Rockland for the time period 1995-1998. To evaluate possible trends over time, results of the 1995-1998 analysis were compared to the results of the initial investigation that examined cancer incidence in these four towns between 1982 and 1994.

A. Cancer Incidence in the Town of Weymouth (Table 1)

During the time period 1995-1998, cancer incidence in Weymouth occurred approximately at or near the expected rate for the majority of cancer types evaluated. The exception was lung cancer, which occurred statistically significantly more often than expected.

Although the incidence of bladder cancer among males and females combined was slightly higher than expected, this increase was not statistically significant (SIR=129, 95% CI=97-169). Similar trends were observed when males and females were evaluated separately. This is in contrast to observations for this cancer during 1982-1994, in which the incidence of bladder cancer was slightly lower than expected for both males and females.

During the 13-year time period 1982-1994, the incidence of brain cancer in Weymouth was slightly lower than expected. However, during the more recent time period 1995-1998, residents of this town experienced brain cancer slightly more often than expected based on the state rate (19 cases observed vs. 15.2 expected). The increase was not statistically significant

and was primarily the result of an increase of this cancer type among males (12 cases observed vs. 8.3 expected).

During 1995-1998, the incidence of kidney cancer townwide was slightly higher than expected based on the state rate (31 cases observed vs. 27 expected). This was primarily due to an increase among females of approximately three cases over the expected number (14 cases observed vs. 11 cases expected) and did not represent a statistically significant elevation. During the earlier time period 1982-1994, kidney cancer occurred slightly less often than expected in Weymouth.

Although a statistically significant elevation in the incidence of leukemia was observed in Weymouth during the 1982-1994 time period, leukemia occurred slightly less often than expected during 1995-1998 (20 cases observed vs. 23.1 expected). Further analysis revealed lower than expected incidence of leukemia among males (11 cases observed vs. 12.7 expected, SIR=87) and females (9 cases observed vs. 10.4 expected, SIR=86) when evaluated separately. Therefore, it appears that the rate of leukemia in Weymouth has decreased in more recent years.

During 1995-1998, the overall rate of liver cancer in Weymouth was approximately at the expected rate (7 cases observed vs. 7.4 expected). However, females experienced about twice the expected rate (4 cases observed vs. 2.1 expected) while males experienced almost half the expected rate (3 cases observed vs. 5.4 expected). For both males and females, the observed number of cases was not significantly different from the expected number. During 1982-1994, the incidence of liver cancer was slightly lower than expected among both males and females.

A statistically significant elevation in the incidence of lung cancer was noted for Weymouth as a whole between 1995 and 1998 (223 cases observed vs. 166.5 expected, SIR=134, 95% CI=117-153). When evaluated separately by gender, both males and females experienced statistically significant increases during this time period (113 cases among males observed vs. 89.1 expected, SIR=127, 95% CI=105-153; 110 cases among females observed vs. 77.4 expected, SIR=142, 95% CI=117-171). The townwide incidence of lung cancer was also statistically significantly elevated among males and females and among males and females combined for the 1982-1994 time period. Further analysis of the SIRs associated with each

increase reveal that the incidence of lung cancer in Weymouth may be increasing relative to the state rate.

The incidence of NHL was approximately as expected in Weymouth between 1995 and 1998 (45 cases observed vs. 43.3 expected). However, the overall rate represented a slight increase in this cancer type among males (27 cases observed vs. 21.9 expected) and a slight decrease among females (18 cases observed vs. 21.4 expected). Although the overall rate of NHL was slightly lower than expected during 1982-1994, similar gender-specific trends were observed during this earlier time period. Analysis of NHL incidence over time in Weymouth suggests that although the incidence of this cancer is not elevated in Weymouth it may be increasing relative to the state rate; during 1982-1986, 25 Weymouth residents were diagnosed with NHL compared to 35.4 expected. During 1987-1994, 73 individuals were diagnosed compared to 74.3 expected.

Pancreatic cancer occurred approximately equal to expected in Weymouth during 1995-1998 (25 cases observed vs. 24.7 expected). Again, the incidence of this cancer was relatively higher among males (14 cases observed vs. 11.4 expected) than females (11 cases observed vs. 13.4 expected). For both males and females, the observed number of cases was not statistically different from the expected number. The overall incidence rate of pancreatic cancer in Weymouth during 1982-1994 was also approximately equal to the expected rate. However, during the 5-year time period 1982-1986, a statistically significant elevation in the incidence of pancreatic cancer was observed. This was primarily due to a statistically significant increase in the number of cases reported among females during this time period. In contrast, during 1987-1994 both males and females in Weymouth experienced a decrease in the incidence of this cancer type.

B. Cancer Incidence in Weymouth Census Tracts

The following sections describe the results of the cancer incidence analysis in Weymouth by census tract. Although SIRs were not calculated for many cancer types in specific census tracts due to the small number of observed cases (i.e., less than five), the expected number of cases was calculated to determine whether excess numbers of cases were occurring.

1) Census Tract 4221 (Table 2)

With a few exceptions noted below, the incidence of cancer in census tract (CT) 4221, located in South Weymouth adjacent to the SWNAS, was approximately at or near the expected rate for the eight cancer types evaluated in this report.

In CT 4221, kidney cancer occurred more than three times as often as expected during 1995-1998 (8 cases observed vs. 2.2 expected, SIR=357). Although this finding was statistically significant, the relatively wide 95% confidence interval (154-704) suggests that the increased SIR is somewhat unstable. The observed elevation was due to an increase of approximately 4 cases among males and 2 cases among females. The incidence of kidney cancer was lower than expected in this census tract for the 1982-1994 time period.

Although the incidence of leukemia was elevated during the 13-year time period 1982-1994 (most notably among males during 1987-1994), leukemia occurred at about the expected rate in CT 4221 during 1995-1998 (2 cases observed vs. 1.9 expected). It appears that the increase in leukemia incidence observed during 1987-1994 has not persisted over time in this CT.

Although the incidence of lung cancer was slightly lower than expected during 1982-1994 (37 cases observed vs. 39.2 expected), a small elevation in this cancer type was observed in CT 4221 during 1995-1998 (16 cases observed vs. 13.6 expected). The elevation was based on approximately two or three additional cases and did not represent a statistically significant elevation. This trend was consistent among males and females when evaluated separately by gender.

Although the incidence of NHL was elevated in CT 4221 during 1982-1994, NHL occurred at approximately the expected rate during 1995-1998 (4 cases observed vs. 3.5 expected). Further analysis by gender revealed similar trends among males and females in this CT indicating that the incidence of NHL in CT 4221 may be declining somewhat and approaching the state rate.

During the 13-year time period 1982-1994, the incidence of pancreatic cancer in CT 4221 was lower than expected. In contrast, a statistically significant elevation in this cancer type was

observed in this CT during 1995-1998 (6 cases observed vs. 2.0 expected, SIR=305). However, the relatively small number of pancreatic cancer cases that occurred during this time period and the wide 95% confidence interval (111-664) indicate that the increased SIR is somewhat unstable. Therefore, it is uncertain based on this data whether the incidence of pancreatic cancer is increasing in this area.

During 1995-1998, several types of cancer occurred at approximately the expected rate (i.e., either one case higher or lower than expected). These included cancers of the bladder, brain, and liver, leukemia, and NHL.

2) Census Tract 4222 (Table 3)

Census tract 4222 is located in South Weymouth and contains a large portion of the SWNAS. In general, incidence rates were approximately at or near the expected rates in this area of town for most of the cancer types evaluated. While some cancer types occurred less frequently than expected in this CT (e.g., leukemia and pancreatic cancer), others occurred more frequently (bladder cancer, brain cancer, kidney cancer, lung cancer, and NHL). However, the majority of the increases were based on only a few additional cases above the expected number (i.e., within three cases) and, with the exception of lung cancer, none of the observed elevations were statistically significant.

The incidence of bladder cancer was slightly elevated in Weymouth CT 4222 during the 4-year time period 1995-1998 (7 cases observed vs. 5.1 expected), primarily due to an increase of approximately two cases among females in this CT. During 1982-1994, both males and females experienced lower than expected rates of bladder cancer.

Although both males and females in CT 4222 experienced a decreased rate of brain cancer during the 13-year time period 1982-1994, this cancer occurred more than twice as often as expected during 1995-1998 (5 cases observed vs. 2.1 expected). However, this increase was not statistically significant. Further analysis by gender revealed that females in this CT experienced approximately twice the incidence of brain cancer, while males experienced approximately three times the incidence. Again, these elevations were based on small increases of only one and two cases, respectively, and were not statistically significant.

Although the incidence of leukemia in this census tract appeared to increase among both males and females during 1982-1994 (14 cases observed vs. 8.1 expected), a decline in the incidence has occurred in more recent years (i.e., 1995-1998) and is closer to the expected rate. During 1995-1998, two individuals in CT 4222 were diagnosed with leukemia where approximately three cases were expected. In contrast, leukemia occurred about as expected during 1982-1986 while a statistically significant elevation in the incidence of this cancer was noted between 1987-1994. The more recent observations during 1995-1998 suggest that the increase in the number of individuals diagnosed with leukemia in Weymouth CT 4222 is not persisting over time.

As noted above, a statistically significant elevation in the incidence of lung cancer was observed in CT 4222 during 1995-1998 (31 cases observed vs. 20.7 expected, SIR=150, 95% CI=102-212). Further analysis by gender revealed similar trends among males and females, however, the number of individuals diagnosed with lung or bronchus cancer was not significantly different from the expected number for each gender when evaluated separately. Although the incidence of this cancer in CT 4222 was also significantly higher than expected during 1982-1994 (79 cases observed vs. 61.2 expected, SIR=129, 95% CI=102-161), it appears that the rate of lung cancer in this census tract may be further increasing over time.

During 1995-1998, residents of CT 4222 experienced a non-significant elevation in the incidence of NHL (9 cases observed vs. 5.5 expected, SIR=163). This increase was most notable among males who experienced approximately twice the expected rate of NHL (6 cases observed vs. 2.9 expected, SIR=207). This pattern was different from that observed during 1982-1994 during which time NHL occurred less often than expected among both males and females (11 cases observed vs. 14.5 expected). However, further examination of trends over time suggests that the incidence of NHL may be increasing in CT 4222 relative to the state rate. Between 1982 and 1986, NHL was reported among two individuals compared with 4.8 cases expected. However, during 1987-1994, the incidence of NHL was closer to the state rate (9 cases observed vs. 9.7 expected) and in more recent years (i.e., 1995-1998), although not statistically elevated, the rate of this cancer type in CT 4222 has surpassed the state rate.

Several cancer types occurred at approximately the expected rate in CT 4222 during 1995-1998. Specifically, the observed numbers of individuals diagnosed with kidney cancer, liver cancer, and pancreatic cancer were within one case of the expected numbers.

3) Cancer Incidence in Weymouth CT 4223 through CT 4228 (Tables 4 through 9)

In general, with a few exceptions noted below, during 1995-1998, the incidence of cancer in census tracts 4223 through 4228 was approximately at or near the expected rates for the eight cancer types evaluated in this report. As described below, the only statistically significant elevations observed were in the incidence of lung cancer among males and females combined in CTs 4223 and 4228, and among females in CT 4223. A statistically significant elevation was also observed in the incidence of NHL among males in CT 4224. Complete cancer incidence results for CTs 4223 through 4228 are presented in Tables 4 through 9.

During 1982-1994, a statistically significant elevation in the incidence of brain cancer was noted in CT 4227 (9 cases observed vs. 3.8 expected, SIR=239, 95% CI=109-455). However, more recent data shows that brain cancer in this CT occurred about as often as expected during 1995-1998 (1 case observed vs. 1.2 expected).

During the time period 1987-1994, leukemia was significantly elevated among males in CT 4224. The incidence of leukemia was slightly elevated among males in this census tract during 1995-1998, with one additional case over the expected number (3 cases observed vs. 1.9 expected). However, leukemia incidence occurred less often than expected in CTs 4223, 4225, and 4226, but slightly more often than expected in CT 4227 (3 cases observed vs. 1.7 expected) and CT 4228 (5 cases observed vs. approximately 2 expected).

During 1995-1998, statistically significant elevations in the incidence of lung cancer were observed among males and females combined and among females in CT 4223. CT 4228 also experienced a statistically significant elevation in the incidence of lung cancer during the more recent time period 1995-1998. This is in contrast to trends observed in these two census tracts during 1982-1994 during which time the incidence of lung cancer was lower than or approximately equal to the expected rates. Further, the incidence of lung cancer was significantly elevated in CTs 4225 and 4227 during the 13-year time period 1982-1994.

Although elevations were also observed in this cancer type during 1995-1998, the increases in more recent years were not statistically significant.

The incidence of NHL was lower than or approximately equal to the expected rate for CTs 4223 through 4228 during the 4-year time period 1995-1998. As noted above, the exception was males in CT 4224, who experienced a significantly higher rate of NHL than expected during this time period (8 cases observed vs. 3.3 expected, SIR=241). However, the small number of cases and the wide 95% confidence interval (104-475) suggest that this SIR is somewhat unstable. Data show that the incidence of NHL among males in this CT was slightly lower than expected during the earlier time period (i.e., 1982-1994).

During 1995-1998, liver cancer occurred at the expected rate or less often than expected in CTs 4223, 4224, 4225, 4226, 4227, and 4228. Slight elevations in the incidence of bladder cancer and pancreatic cancer were observed in some of these CTs, however, these increases were based on only a few additional cases over the expected number and were not statistically significant.

C. Cancer Incidence in the Town of Abington (Table 10)

During the time period 1995-1998, the incidence of cancer in Abington was lower than or approximately equal to the expected rates for the eight cancer types evaluated in this report. As described below, bladder cancer and lung cancer occurred slightly more often than expected, however, neither of these elevations was statistically significant.

Although the incidence of bladder cancer was lower than expected in the town of Abington during 1982-1994, a slight but non-significant elevation in this cancer type was observed during more recent years (i.e., 1995-1998) (12 cases observed vs. 9.6 expected, SIR=125, 95% CI=64-218). This was primarily due to an increase of approximately 2 cases over the expected number among males in this town (9 cases observed vs. 6.8 expected).

Residents of Abington experienced a lower than expected rate of brain cancer during the 4-year time period 1995-1998 (1 case observed vs. 3.7 expected). This pattern was different from that seen in the previous time period 1982-1994, during which brain cancer occurred more

often than expected (15 cases observed vs. 11.0 expected). It is unclear whether the trend of declining incidence in brain cancer will continue in Abington over time.

Although the incidence of kidney cancer in Abington was lower than expected during the 13-year time period 1982-1994, incidence was about as expected during more recent years (i.e., 1995-1998) (7 cases observed vs. 6.4 expected). However, this was based on a slight increase among males in the town (5 cases observed vs. 3.9 expected) and a slight decrease among females (2 cases observed vs. 2.5 expected).

During 1995-1998, the overall incidence of leukemia in Abington was approximately equal to the state rate (6 cases observed vs. 5.6 expected). Similar trends were observed during the earlier time period 1982-1994. However, during the more recent years (i.e., 1995-1998), all six cases were diagnosed among males compared to 3.1 cases expected. No cases of leukemia were observed among females in the town.

The incidence of lung cancer in Abington during 1995-1998 was approximately 20% higher than expected (46 cases observed vs. 38.6 expected, SIR=119). This elevation was not statistically significant. Further analysis of lung cancer incidence by gender revealed that males in this town experienced lung cancer relatively more often than females during 1995-1998 (30 cases among males observed vs. 20.9 expected, SIR=144; 16 cases among females observed vs. 17.7 expected, SIR=90). Again, the observed numbers of cases were not significantly different from the expected number. This pattern of disease was very similar to trends observed between 1982 and 1994, during which time the overall rate of lung cancer in Abington was approximately 20% higher than expected and incidence among males was significantly elevated.

The overall rate of NHL in Abington was lower than the state rate during 1982-1994. A decrease in incidence of similar magnitude was also observed during more recent years (i.e., 1995-1998) (8 cases observed vs. 10.4 expected, SIR=77). However, separate analysis by gender revealed different trends between the two time periods. During the earlier time period, 1982-1994, females in Abington experienced NHL at approximately the rate expected while males were diagnosed about half as often as expected, influencing the overall rate. In contrast, during 1995-1998, no cases of NHL were diagnosed among females (where approximately five cases

were expected) while the incidence among males was higher than expected based on the state rate (8 cases observed vs. 5.4 expected, SIR=149).

No cases of liver cancer were reported in Abington during the 4-year time period 1995-1998. Pancreatic cancer occurred at approximately the expected rate during more recent years (5 cases observed vs. 5.8 expected, SIR=86). A similar trend was observed in the incidence of pancreatic cancer during the earlier time period 1982-1994.

D. Cancer Incidence in Abington Census Tracts

The following sections describe the results of the cancer incidence analysis in Abington by census tract. Although SIRs were not calculated for many cancer types in specific census tracts due to the small number of observed cases (i.e., less than five), expected numbers were calculated to determine whether excess numbers of cases were occurring. Complete cancer incidence data for Abington CTs can be found in Tables 11 through 13.

1) Census Tract 5201 (Table 11)

CT 5201 is located in the southern portion of the town of Abington. In general, during 1995-1998, the incidence of cancer in Abington CT 5201 was approximately at or near the expected rates for the eight cancer types evaluated in this report. Brain cancer, leukemia, liver cancer, lung cancer, NHL, and pancreatic cancer occurred less often than expected based on state rates. Slight increases in the rates of bladder cancer and kidney cancer were observed during 1995-1998, however, neither of these elevations was statistically significant.

Although bladder cancer occurred less often than expected during 1982-1994, the incidence of this cancer type in CT 5201 was higher than expected during more recent years (i.e., 1995-1998) (7 cases observed vs. 4.4 expected). This was primarily due to an increase in the incidence of bladder cancer among males (6 cases observed vs. 3.1 expected). However, the elevation among males was based on less than three additional cases over the expected number and was not statistically significant (SIR=195, 95% CI=71-425). During the earlier time period 1982-1994, bladder cancer occurred at approximately the expected rate among males in CT 5201.

Kidney cancer occurred near the expected rate during 1995-1998 (4 cases observed vs. 2.8 expected). Males experienced approximately one additional case over the expected number during this time period (3 cases observed vs. 1.7 expected). In contrast, the overall rate of kidney cancer was lower than expected in CT 5201 during 1982-1994, primarily due to a lower than expected rate of kidney cancer among males. It appears that while the incidence of kidney cancer among females has remained at the expected rate, incidence rates have increased over time among males in this area of Abington.

During the 13-year time period 1982-1994, lung cancer occurred slightly more often than expected in CT 5201. However, in more recent years (i.e., 1995-1998), the incidence of lung cancer in this census tract was lower than expected based on the state rate (12 cases observed vs. 16.9 expected). Similar trends were observed among males and females when evaluated separately by gender.

2) Census Tract 5202.01 (Table 12)

CT 5202.01 is located in the northwest area of the town of Abington and contains a portion of the SWNAS property. During 1995-1998, cancer incidence in CT 5202.01 was lower than or approximately equal to expected rates for the majority of the eight cancer types evaluated. Specifically, kidney cancer, leukemia, and NHL occurred less frequently than expected based on state rates during this time period. The overall incidence rates of brain and liver cancer were equal to the expected rates. While slight elevations in the incidence of bladder cancer, lung cancer, and pancreatic cancer were observed, the numbers of individuals diagnosed with these cancers were not significantly different from the expected numbers.

The incidence of bladder cancer during 1982-1994 was slightly elevated in CT 5202.01 and remained so during 1995-1998 (4 cases observed vs. 2.3 expected). Although a statistically significant elevation was observed for females in the earlier time period (i.e., 1982-1994), the increase among females in this census tract during 1995-1998 was essentially one additional case.

Although leukemia occurred more often than expected in this census tract during 1982-1994 (6 cases observed vs. 3.5 expected), it appears that the rate of leukemia may be declining in

this area of Abington. Analysis of more recent data (i.e., 1995-1998) shows a lower than expected overall incidence of this cancer type (1 case observed vs. 1.4 expected).

During 1995-1998, the incidence of lung cancer was slightly but non-significantly elevated in CT 5202.01 with respect to the state rate (15 cases observed vs. 9.6 expected). In contrast, fewer individuals were diagnosed with this cancer than expected during 1982-1994. However, in both time periods, the observed number of individuals with lung or bronchus cancer was not significantly different from the expected number.

The slight elevation in the incidence of pancreatic cancer observed among females during 1982-1994 in CT 5202.01 (4 cases observed vs. 1.8 expected) appears to have persisted over time. During 1995-1998, two females in this census tract were diagnosed with pancreatic cancer where less than one case was expected. However, the observed elevation was based on approximately one case over the expected number and was not statistically significant.

3) Census Tract 5202.02 (Table 13)

Census tract 5202.02 is located southwest of CT 5202.01 in the western portion of Abington bordering the city of Brockton. The majority of cancer types evaluated occurred less often than expected in this area of Abington during 1995-1998. Specifically, incidence rates for bladder cancer, brain cancer, liver cancer, and NHL were below Massachusetts state rates for this time period. Kidney cancer, leukemia, lung cancer, and pancreatic cancer occurred slightly more often than expected, however, none of the observed elevations were statistically significant. However, a statistically significant elevation in lung cancer was observed among males in CT 5202.02 during 1995-1998.

Although brain cancer occurred at almost twice the expected rate in CT 5202.02 during 1982-1994, no cases were reported during 1995-1998. Slightly more than one case was expected during this time.

As previously mentioned, a statistically significant elevation in lung cancer was observed among males during 1995-1998 (12 cases observed vs. 6.1 expected, SIR=195, 95% CI=101-341). A statistically significant elevation in the incidence of lung cancer was also observed in this census tract overall during 1982-1994 (46 cases observed vs. 31.6 expected, SIR=146, 95%

CI=107-194). This was primarily the result of an elevation among males during this time period. In more recent years (i.e., 1995-1998), the overall rate of lung cancer remained elevated but the observed number of cases among males and females combined was not significantly different from the expected number. However, the statistically significant elevation observed among males in this census tract during 1982-1994 has persisted over the 1995-1998 time period. Among females, although the incidence of lung cancer remained slightly elevated in recent years, rates have declined over time.

E. Cancer Incidence in the Town of Hingham (Table 14)

During 1995-1998, cancer incidence in Hingham was approximately at or near expected rates for the majority of cancer types evaluated. The exception included lung cancer, which occurred significantly less often than expected in the town as a whole. Elevations were observed during this time period in the incidence of bladder cancer, liver cancer, and pancreatic cancer. None of the elevations were statistically significant.

Although not statistically significant, an elevation was observed in the overall incidence of bladder cancer in Hingham during 1995-1998 (20 cases observed vs. 14.9 expected, SIR=134, 95% CI=82-207). This is in contrast to rates observed in Hingham for the 13-year time period 1982-1994, during which time bladder cancer occurred less often than expected based on the state rate. When evaluated separately by gender, males and females experienced increases in the incidence of this cancer of similar magnitude during 1995-1998.

Residents of Hingham experienced brain cancer slightly less frequently than expected during 1995-1998 (4 cases observed vs. 5.6 expected). It appears that the rate of brain cancer in this town has been declining over time; during 1982-1986, a non-significant elevation was observed for this cancer type but incidence was approximately equal to the expected rate during 1987-1994. However, in all three time periods, females experienced relatively more cases of brain cancer than males in Hingham.

During the 13-year time period 1982-1994, the incidence of kidney cancer in Hingham was lower than expected. However, during more recent years (i.e., 1995-1998), the incidence rate for this cancer type was equal to the state rate (10 cases observed vs. 10.0 expected,

SIR=100). In this more recent time period, males experienced approximately one more case than expected and females experienced approximately one less case than expected.

Both males and females Hingham experienced leukemia less often than expected during 1995-1998 (5 cases observed vs. 8.5 expected). This trend is consistent with that observed in the earlier 13-year time period 1982-1994.

The incidence of liver cancer was slightly but non-significantly elevated townwide during the 4-year time period 1995-1998 (5 cases observed vs. 2.8 expected). Males and females each experienced approximately one additional case over the expected number, however, none of the observed elevations were statistically significant. In contrast, the incidence of liver cancer was lower than expected in Hingham during 1982-1994.

During 1982-1994, a statistically significant decrease in the incidence of lung cancer was observed in the town of Hingham. This trend has persisted over time where more recent data (i.e., 1995-1998) also indicate a statistically significant decrease in incidence rates of this cancer (42 cases observed vs. 60.6 expected, SIR=69, 95% CI=50-94). Moreover, analysis of this data suggests that the incidence rate for this cancer type may be declining over time townwide.

NHL occurred approximately as often as expected in Hingham during the 4-year time period 1995-1998 (16 cases observed vs. 15.6 expected). This was similar to trends observed during 1982-1994.

Although the incidence of pancreatic cancer was significantly lower than expected during 1982-1994, analysis of more recent data (i.e., 1995-1998) reveals a slight elevation in the incidence of this cancer type townwide (11 cases observed vs. 8.9 expected). However, this increase was based on approximately two additional cases over the expected number and was not statistically significant.

F. Cancer Incidence in Hingham Census Tracts

The following sections describe the results of the cancer incidence analysis in Hingham by census tract. Although SIRs were not calculated for many cancer types in specific census tracts due to the small number of observed cases (i.e., less than five), expected numbers were

calculated to determine whether excess numbers of cases were occurring. Complete cancer incidence data for Hingham CTs can be found in Tables 15 through 17.

1) Census Tract 5011.01 and 5011.02 (Tables 15 and 16)

CTs 5011.01 and 5011.02 are located in the northern portion of Hingham along the coast. During 1995-1998, cancer occurred about as expected in these two census tracts. Some of the cancer types occurred less frequently in these census tracts than expected (e.g., bladder cancer, leukemia, lung cancer, and NHL in CT 5011.01 and kidney cancer, leukemia, lung cancer, and pancreatic cancer in CT 5011.02) while others occurred more frequently than expected (e.g., Hodgkin's disease, liver cancer, and pancreatic cancer in CT 5011.01 and bladder cancer, liver cancer, and NHL in CT 5011.02). However, none of the observed increases or decreases in these census tracts were statistically significant.

Bladder cancer occurred slightly more frequently than expected during 1995-1998 in CT 5011.02 (9 cases observed vs. 5.3 expected). In contrast, a statistically significant decrease in the incidence of bladder cancer was observed in this census tract for the earlier time period 1982-1994. Although a slight but non-significant elevation in the incidence of bladder cancer among males in CT 5011.01 was observed during 1982-1994, most notably during the later years 1987-1994, bladder cancer among males occurred as expected during more recent years (i.e., 1995-1998) (2 cases observed vs. 2.0 expected).

Despite a slight increase in the incidence of brain cancer in CT 5011.02 during 1982-1994, the rate of brain cancer in this census tract was as expected based on the state rate during 1995-1998 (2 cases observed vs. 2.0 expected).

During 1982-1994, lung cancer occurred less often than expected in CT 5011.01 and the overall rate was approximately as expected in CT 5011.02. However, a statistically significant elevation in lung cancer was noted among females in CT 5011.02. Although an increase among females was observed during the later half of this 13-year time period (i.e., 1987-1994), the elevation was most apparent (and statistically significant) during 1982-1986. In contrast, the incidence of lung cancer among females in CT 5011.02 was lower than expected during 1995-1998 (13 cases observed vs. 21.7 expected). Therefore, it appears that the incidence of this

cancer type among females in CT 5011.02 may be declining over time. As seen during 1982-1994, males in CT 5011.02 experienced a lower than expected rate of lung cancer during 1995-1998 (5 cases observed vs. 11.5 expected).

2) Census Tract 5012 (Table 17)

CT 5012 is located in the southern portion of Hingham and abuts the SWNAS property. In general, the eight cancer types evaluated in this report occurred approximately at or near expected rates during 1995-1998. Although some cancer types occurred more often than expected, as described below, none of the observed elevations were statistically significant.

Despite a lower than expected rate of bladder cancer in CT 5012 during 1982-1994, the incidence of this cancer type was slightly increased relative to the state rate during 1995-1998 (9 cases observed vs. 6.8 expected). This elevation was primarily due to an increase of approximately two cases over the expected number among males in this area of Hingham. The observed elevation was not statistically significant.

A statistically significant decrease in the incidence of lung cancer was noted among males and females combined and among males in CT 5012 during the earlier time period 1982-1994. Similar trends were observed during 1995-1998, although the decrease was not statistically significant during this time period (24 cases observed vs. 27.9 expected, SIR=86, 95% CI=55-128).

During the 4-year time period 1995-1998, pancreatic cancer occurred more often than expected in CT 5012 (6 cases observed vs. 4.1 expected). This finding was primarily the result of an increase of approximately two cases among males in this census tract and was not a statistically significant elevation. In contrast, the incidence rate was about half the expected rate during the earlier time period 1982-1994. Therefore, it appears that the incidence of pancreatic cancer may be increasing over time in this census tract.

G. Cancer Incidence in the Town of Rockland (Table 18)

During 1995-1998, cancer incidence in Rockland was approximately at or near the expected rate for the majority of cancer types evaluated with the exception of lung cancer. For

lung cancer, a statistically significant elevation occurred in Rockland overall. Statistically significant elevations in this cancer type were also observed when males and females were evaluated separately.

Despite a slightly decreased incidence of bladder cancer in Rockland during 1982-1994, bladder cancer occurred more frequently than expected based on the state rate during 1995-1998 (15 cases observed vs. 11.2 expected). However, this elevation was based on only a few additional cases over the expected number and was not a statistically significant difference. Further analysis of bladder cancer by gender revealed that the incidence was as expected among females (3 cases observed vs. 3.3 expected) but increased among males (12 cases observed vs. 7.9 expected). Again, the elevation observed in males was not statistically significant.

During 1995-1998, brain cancer occurred about as often as expected among both males and females in Rockland (4 cases observed vs. 4.4 expected). In contrast, the incidence of brain cancer was slightly elevated during the earlier 13-year time period 1982-1994, most notably among females.

During the 13-year time period 1982-1994, residents of Rockland experienced leukemia less often than expected based on the state rate. However, more recent data (i.e., 1995-1998) indicates that leukemia occurred approximately at the expected rate during this time (7 cases observed vs. 6.6 expected).

Although the incidence of liver cancer was slightly elevated townwide during 1982-1994, liver cancer occurred about as expected during the 4-year time period 1995-1998 (2 cases observed vs. 2.1 expected). Incidence rates for liver cancer were similar among males and females in Rockland.

As previously mentioned, statistically significant elevations in the incidence of lung cancer were observed among both males and females in Rockland during 1995-1998 (82 cases observed vs. 45.7 expected, SIR=179, 95% CI=143-223). Specifically, females experienced approximately twice the expected rate of lung cancer (43 cases observed vs. 21.2 expected, SIR=203, 95% CI=147-273) while males experienced about 60% more cases than expected (39 cases observed vs. 24.6 expected, SIR=159, 95% CI=113-217). In contrast, only a slight

elevation in the incidence of this cancer type was observed during 1982-1994. During this time period, lung cancer was slightly, but not significantly, elevated among females in Rockland. Analysis by smaller time periods suggests that the incidence of lung cancer in Rockland may be increasing over time, especially among females.

NHL occurred about half as often as expected in Rockland during the 4-year time period 1995-1998 (6 cases observed vs. 12.1 expected, SIR=49). The number of observed cases was not significantly different from the number of expected cases (95% CI=18-107). Similar trends were observed during 1982-1994, however, analysis by smaller time period suggests that NHL incidence in Rockland may be decreasing over time.

During 1995-1998, residents of Rockland experienced slightly more cases of pancreatic cancer than expected (8 cases observed vs. 6.8 expected). The incidence rates for pancreatic cancer were below the state rate for the earlier time period 1982-1994.

Fewer individuals in Rockland were diagnosed with kidney cancer during 1995-1998 than expected based on state rates. Similar trends were observed between 1982-1994.

H. Cancer Incidence in Rockland Census Tracts

The following sections describe the results of the cancer incidence analysis in Rockland by census tract. Again, SIRs were not calculated for many cancer types in specific census tracts due to the small number of observed cases (i.e., less than five), however, expected numbers were calculated to determine whether excess numbers of cases were occurring. Complete cancer incidence data for Rockland CTs can be found in Tables 19 and 20.

1) Census Tract 5021 (Table 19)

Census tract 5021 is located in the southern portion of Rockland. During 1995-1998, four of the eight cancer types evaluated occurred less frequently than expected in CT 5021 (e.g., brain cancer, kidney cancer, leukemia, and NHL) while others occurred more frequently than expected (e.g., bladder cancer, liver cancer, lung cancer, and pancreatic cancer). However, with the exception of lung cancer, for which the incidence rate was significantly elevated, none of the observed increases or decreases were statistically significant.

The incidence of bladder cancer was approximately at the expected rate in CT 5021 during 1995-1998. One additional case over the expected number was diagnosed (7 cases observed vs. 5.9 expected, SIR=119). In comparison, the incidence of bladder cancer in CT 5021 was slightly decreased during 1982-1994.

Brain cancer occurred at approximately the expected rate in CT 5021 during 1995-1998 (2 cases observed vs. 2.7 expected). In contrast, the rate of brain cancer was slightly but non-significantly elevated in CT 5021 during 1982-1994.

During 1995-1998, kidney cancer occurred about half as often as expected in CT 5201 (2 cases observed vs. 4.3 expected). The incidence of kidney cancer was also lower than expected in this census tract during the 1982-1994 time period.

Leukemia occurred less often than expected than expected in CT 5021 during 1995-1998 (2 cases observed vs. 3.8 expected). The overall rate of leukemia in CT 5021 was also lower than expected during the earlier time period 1982-1994, however, during this time period, rates were about as expected among females but lower than expected among males.

The incidence of liver cancer was about as expected in CT 5021 based on the state rate during 1995-1998 (2 cases observed vs. 1.2 expected). The overall rate of liver cancer in CT 5021 was higher than expected during 1982-1994 (5 cases observed vs. 2.2 expected).

During 1995-1998, a statistically significant elevation in the incidence of lung cancer was observed in Rockland CT 5021 (43 cases observed vs. 24.9 expected, SIR=173, 95% CI=125-233). Although both males and females experienced increases in incidence, only the elevation among females was statistically significant (23 cases observed vs. 11.3 expected, SIR=203, 95% CI=129-304). Although not statistically significant, elevations in the incidence of this cancer type in CT 5021 were also observed during the earlier time period 1982-1994. Analysis by smaller time period suggests that incidence rates for this census tract as a whole may be increasing over time.

Residents of CT 5021 experienced NHL less often than expected during 1995-1998 (3 cases observed vs. 6.9 expected). Although not as pronounced, a decrease in the incidence of

NHL was also noted during the 13-year time period 1982-1994. This was the result of a slight increase in incidence during 1982-1986 and a decrease in incidence during 1987-1994.

Pancreatic cancer occurred about as often as expected in CT 5021 during 1995-1998 (4 cases observed vs. 3.6 expected) with similar rates for males and females. These trends were similar to patterns of pancreatic cancer in this area of Rockland during 1987-1994. During 1982-1994, the incidence of pancreatic cancer in CT 5021 was slightly lower than expected among both males and females.

2) Census Tract 5022 (Table 20)

CT 5022 is located in the northern portion of Rockland and includes part of the SWNAS property. During 1995-1998, bladder cancer, kidney cancer, leukemia, and pancreatic cancer all occurred slightly more often than expected in this census tract. A statistically significant elevation was noted for lung cancer. Brain cancer occurred at approximately the rate expected during this time period and incidence rates were lower than expected for liver cancer and NHL.

During 1995-1998, bladder cancer occurred approximately 50% more often than expected in CT 5022 (8 cases observed vs. 5.3 expected). However, the increase was based on less than three additional cases over the expected number and was not statistically significant (95% CI=65-298). The increase was most notable among males in this census tract (6 cases observed vs. 3.6 expected). In contrast, the incidence of this cancer type was lower than the state rate during 1982-1994.

Although residents of CT 5022 experienced a decreased rate of leukemia during the 13-year time period 1982-1994, the incidence of this cancer was slightly elevated during more recent years (i.e., 1995-1998) (5 cases observed vs. 2.9 expected). Again, the observed number of cases was not significantly different from the expected number. During this more recent time period, two males were diagnosed with leukemia where approximately 1.5 cases were expected and three females were diagnosed where approximately 1.3 cases were expected. In contrast, incidence rates among both males and females were slightly lower than expected during 1982-1994.

Lung cancer occurred more often than expected in CT 5022 during 1995-1998 (39 cases observed vs. 20.9 expected). This increase represented a statistically significant elevation (SIR=187, 95% CI=133-256). Further analysis revealed statistically significant elevations among males (19 cases observed vs. 11.0 expected, SIR=172, 95% CI=104-269) and females (20 cases observed vs. 9.8 expected, SIR=203, 95% CI=124-314) when evaluated separately by gender. However, during the 1982-1994 time period, the incidence of lung cancer among both males and females was about as expected based on the state rate.

NHL occurred slightly less often than expected in CT 5022 during 1995-1998 (3 cases observed vs. 5.3 expected). Similar trends were observed in this census tract during the 1982-1994 time period.

Although approximately one case was expected, no diagnoses of liver cancer were reported in CT 5022 during 1995-1998. Finally, the observed numbers of diagnoses of brain cancer, kidney cancer, and pancreatic cancer were within one cases of the expected numbers based on the state rates.

V. REVIEW OF CANCER RISK FACTOR INFORMATION

As previously mentioned, cancer is not just one disease but is a term used to describe a variety of different diseases. As such, studies have generally shown that different cancer types have different causes, patterns of incidence, risk factors, latency periods (i.e., period between exposure and development of disease), characteristics and trends in survival. Available information from the MCR related to age and gender patterns, as well as other factors related to the development of cancer (e.g., smoking and occupation), were reviewed for those cancer types that had statistically significant elevations in incidence in Weymouth, Abington, Hingham, and Rockland with particular emphasis on census tracts near the SWNAS. Cancer types for which incidence rates were statistically significantly elevated in the town of Weymouth as a whole or in one of its census tracts between 1995-1998 included lung cancer, kidney cancer, NHL, and pancreatic cancer. In Abington, males in census tract 5202.02 experienced a statistically significant increase in the incidence of lung cancer during this time period. In Rockland, the incidence rate for lung cancer was significantly elevated townwide as well as in both census

tracts during 1995-1998. Information for each of these cancer types was compared to known or established incidence trends to assess whether any unexpected patterns exist among these cases.

Age and gender are risk factors in many types of cancers, including lung cancer, kidney cancer, NHL, and pancreatic cancer. Age- and gender-specific SIRs were calculated for Weymouth, Abington, Hingham, and Rockland to evaluate cancer incidence in comparison to age- and gender-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 known or suggested causal risk factor in several types of cancer, including lung cancer, kidney cancer, and pancreatic cancer. The smoking status of individuals diagnosed with these cancers in towns and CTs evaluated in this report during the years 1995-1998 was reviewed. However, results of smoking status analysis should be interpreted with caution because of the number of individuals for which smoking status was unknown. Although smoking likely played some role in the development of these cancers in the four towns, due to the number of individuals with unknown smoking status, the extent of this role is not clear.

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 to determine the likelihood that occupational factors may have contributed to the development of certain cancers in Weymouth, Abington, Hingham, and Rockland. It should be noted, however, that occupational data reported to the MCR are generally limited to job title and often 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.

Finally, histologic (cell type) distribution was reviewed for diagnoses of lung cancer for towns that experienced increased incidence rates with respect to the state. Patterns of disease were compared to known or established incidence trends to assess whether any unexpected patterns exist in these areas.

A. Lung Cancer

1) Age and Gender Distribution

During the period 1995-1998, the incidence of lung cancer was significantly elevated townwide in Weymouth and Rockland. Statistically significant elevations were also observed in Weymouth CTs 4222, 4223, and 4228, Abington CT 5202.02 (among males only), and Rockland CTs 5021 and 5022.

According to epidemiological literature, the incidence of lung cancer increases sharply with age peaking at about age 60 to 70. Only two percent of lung cancers occur before the age of 40. In addition, lung cancer is generally observed more often among men than women (Blot and Fraumeni 1996, MCR 2000). Lung cancer trends in Weymouth during the 4-year time period 1995-1998 were similar to the expected pattern of this disease. For example, the average age of diagnosis in Weymouth was 67. Further, only three individuals were diagnosed before age 40 (1%). As noted earlier, incidence rates among both males and females in this town were significantly elevated with respect to gender-specific incidence rates for Massachusetts as a whole. However, females in Weymouth experienced relatively more cases of lung cancer than males (SIR=142 for females and SIR=127 for males). Age-specific incidence rates indicate that the elevation in lung cancer incidence among females does not appear to be the result of an elevation in any one age group; increases of similar magnitude were observed in all age groups. However, among males in Weymouth, incidence rates were primarily elevated among individuals younger than 75 years of age.

The age distribution of individuals diagnosed with lung cancer in Weymouth CTs 4222, 4223, and 4228, in which statistically significant elevations in incidence were observed, was similar to the pattern in Weymouth as a whole. However, the gender distributions differed for each census tract. In CT 4222, both males and females experienced elevations in incidence of similar magnitude. In CT 4223, while increases in the rate of lung cancer were noted among both males and females, the elevation was relatively greater and statistically significant among females. Finally, males experienced relatively more cases of this cancer than females in CT 4228. The increase in CT 4228 was borderline statistically significant among males (SIR=178, 95% CI=100-294).

Although not statistically significant, a slight elevation in the incidence of lung cancer was observed in the town of Abington during 1995-1998. As expected, relatively more males were diagnosed with this cancer type in the town overall. Moreover, the average age of diagnosis (68 years) was consistent with the established literature on the pattern of this disease. In CT 5202.02, where a statistically significant elevation in the incidence of lung cancer was seen among males, the average age of diagnosis among males and females combined was 69 years. For males, the average age of diagnosis was 73 years. Further analysis revealed that the elevation in the incidence of lung cancer among males in CT 5202.02 can be most likely attributed to an increase in the diagnosis of this cancer among males aged 65-84 years.

As noted previously, statistically significant elevations in the rate of lung cancer were noted for the town of Rockland as a whole as well as for each of its individual census tracts during the 4-year time period 1995-1998. Review of the gender-specific incidence rates revealed that although both genders experienced a significant elevation in the incidence of this cancer type, females accounted for relatively more lung diagnoses in this town than males. Specifically, the incidence rate among females was approximately twice the expected rate while the incidence among males was about 60% higher than expected based on the state rate. The gender distribution observed townwide was consistent within each of Rockland's two census tracts, CT 5021 and 5022. The average age of diagnosis townwide was 69, which is consistent with the established incidence pattern for this cancer. Further, no individuals were diagnosed under the age of 40 years. The average age of diagnosis in CTs 5021 and 5022 was similar to that seen townwide (67 years and 71 years, respectively). Finally, the observed elevations are not the result of an increase in diagnoses among individuals in any one age group as elevations were observed among age groups 45-64, 65-74, 75-84, and 85+.

2) Smoking Status

More than 80% of all lung cancers are caused directly by smoking cigarettes and many of the rest are due to exposure to second hand smoke, or environmental tobacco smoke (ACS 2000a). An increase in cigarette smoking among women has produced lung cancer incidence rates that more closely resemble those experienced by males. The risk of developing lung cancer depends on the intensity of one's smoking habits (e.g., duration of habit, amount smoked, tar

yield of cigarette, and filter type). Smoking cessation decreases the elevated risk by about 50%, however, former smokers still carry a greater risk of developing lung cancer than those who have never smoked.

In Weymouth, where a statistically significant elevation in the incidence of lung cancer among both males and females was noted, 56% of all individuals diagnosed with this cancer during 1995-1998 were current or former smokers. Only 3% reported themselves as non-smokers. The remainder of the cases had unknown smoking status (41%). In Massachusetts, the respective rates were 73%, 6%, and 21% (see Figure 2). Trends observed in the census tracts where the incidence of lung cancer was significantly increased (e.g., CTs 4222, 4223, and 4228) were similar to those seen in Weymouth overall.

In Abington, smoking patterns townwide were similar to those observed for Massachusetts as a whole (see Figure 3). Seventy percent of the individuals diagnosed with lung cancer during 1995-1998 reported being current or former smokers at the time of diagnosis. The corresponding rate for Massachusetts was 73%. In Abington, smoking status was unknown for 28% of those diagnosed compared to 21% in Massachusetts. A statistically significant elevation was seen in the incidence of lung cancer among males in CT 5202.02. Review of the smoking status information for these individuals indicated that 58% (n=7) were current or former smokers at the time of diagnosis. Twenty-five percent (n=3) did not report smoking information.

Residents of Rockland experienced a statistically significant elevation in the incidence of lung cancer town-wide as well as in both census tracts during 1995-1998. Review of smoking information for individuals diagnosed with this cancer during this time period indicated that 57% were current or former smokers at the time of diagnosis and 4% were non-smokers (see Figure 4). Smoking status was unknown for 39% of those diagnosed. In CT 5021, slightly more than half (51%) of those diagnosed reported themselves as current or former smokers at the time of diagnosis, however, smoking status was unknown for 44% of the cases. In CT 5022, 64% were current or former smokers at the time of diagnosis while smoking status was unknown for 33%.

3) Occupation

Several occupational exposures have been identified as playing a role in the development of lung cancer. For example, workplace exposure to asbestos is an established risk factor for this disease. Underground miners exposed to radon and uranium are also at an increased risk for developing lung cancer. Other occupations potentially associated with this cancer include chemical workers, talc miners and millers, paper and pulp workers, metal workers, butchers and meat packers, vineyard workers, carpenters and painters, and shipyard and railroad manufacture workers. In addition to asbestos and radon, chemical compounds such as arsenic, chloromethyl ethers, chromium, vinyl chloride, nickel chromates, coal products, mustard gas, ionizing radiation, and fuels such as gasoline are also occupational risk factors for lung cancer. Occupational exposure to these compounds in conjunction with cigarette smoking can dramatically increase the risk of developing lung cancer (Blot and Fraumeni 1996).

Review of occupational information for lung cancer cases in the town of Weymouth revealed that 31% of cases reported their occupation as retired or unknown. Only seven percent (n=15) of lung cancer cases reported an occupation that could possibly be associated to the development of this cancer (i.e., shipyard worker). For the remaining individuals (i.e., 62%) the occupational information either indicated a job title not associated with known exposures to potential lung carcinogens or was not specific enough to determine whether the occupation may be associated with exposures that could increase the risk of lung cancer. In CT 4222, three out of thirty-one individuals reported occupations potentially associated with the development of lung cancer while eight (26%) listed occupation as unknown or retired. In CT 4223, 27% (n=11) reported their occupation as retired or unknown. One individual in this census tract reported an occupation possibly associated with lung cancer (e.g., shipyard worker). Finally, in CT 4228, three out of twenty-five individuals diagnosed with lung or bronchus cancer reported occupations that have been associated with this cancer type. Approximately 36% reported their occupation as unknown or retired.

In the town of Abington, 39% of individuals diagnosed with lung cancer during 1995-1998 reported their occupation as retired or unknown. Of the 46 individuals with lung cancer, seven (15%) reported occupations that may have involved exposures related to an increased lung

cancer risk. In CT 5202.02, where a statistical elevation of lung cancer was observed among males, 33% (n=4) of males reported their occupation as retired or unknown. Three males (25%) in this census tract reported occupations that may have exposures related to an increased risk of developing lung cancer.

Review of occupational information for lung cancer in the town of Rockland revealed that 46% of individuals (n=38) diagnosed with lung cancer during 1995-1998 had occupations reported as retired or unknown. Three individuals (4%) reported an occupation that is potentially associated with the development of this cancer. As noted above, significantly elevated incidence rates were observed in both census tracts in Rockland during 1995-1998. While the number of occupations reported as retired or unknown was similar in each CT, all three individuals with occupations potentially associated with lung cancer resided in CT 5021.

4) Histology

Lung cancer is divided into two main types: small cell lung cancer and non-small cell lung cancer. Non-small cell lung cancer is further sub-divided into three types: adenocarcinoma, squamous cell carcinoma, and large-cell undifferentiated carcinoma. The different types of lung cancer occur with different frequencies in the population. The American Cancer Society estimates that approximately 40% of all lung cancers are adenocarcinomas, 30% are squamous cell carcinomas, 20% are small cell cancers, and 10% of cases are large cell carcinomas (ACS 2000a). Rates in Massachusetts were very similar to those seen nationally. Statewide, 40% of all lung cancer diagnoses between 1995 and 1998 were adenocarcinomas, 28% were squamous cell carcinomas, 18% were small cell carcinomas, and 11% were large cell carcinomas.

In Weymouth, the histologic distribution of lung cancer diagnoses between 1995-1998 was somewhat different from that seen in the general population. Of the diagnoses with specific histology classification, 35% were adenocarcinomas, 19% were squamous cell carcinomas, 20% were small cell carcinomas, and 23% were large cell carcinomas. In CT 4222, 52% of lung cancer diagnoses were adenocarcinomas, 16% were squamous cell carcinomas, 12% were small cell carcinomas, and 16% were large cell carcinomas. In CT 4223, 29% were adenocarcinomas, 21% were squamous cell carcinomas, 18% were small cell carcinomas, and 32% were large cell carcinomas. Finally, in CT 4228, 47% were adenocarcinomas, 16% were squamous cell

carcinomas, 16% were small cell carcinomas, and 11% were large cell carcinomas. Similar histologic distributions were observed in Weymouth census tracts that did not experience statistically significant elevations in the incidence of lung cancer.

The overall histologic distribution in Abington was similar to that seen for the town of Weymouth during 1995-1998. Specifically, 38% of the diagnoses with specific histology classification were adenocarcinomas, 16% were squamous cell carcinomas, 16% were small cell carcinomas, and 22% were large cell carcinoma. Among males in CT 5202.02, who experienced a statistically significant elevation in lung cancer, 40% were adenocarcinomas, 20% were squamous cell carcinomas, 10% were small cell carcinomas, and 30% were large cell carcinomas.

The histologic distribution of lung cancer diagnoses in Rockland during 1995-1998 was consistent with the expected pattern of disease. Forty-five percent of diagnoses were adenocarcinomas, 27% were squamous cell carcinomas, 18% were small cell carcinomas, and 7% were large cell carcinomas. Similar trends were observed in each of Rockland's two census tracts (e.g., CTs 5021 and 5022).

B. Kidney Cancer

1. Age and Gender Distribution

Although the number of individuals diagnosed with kidney cancer was not significantly different from the expected number for Weymouth as a whole, residents of CT 4221 experienced a statistically significant elevation in the incidence of kidney cancer during 1995-1998. Although increases were observed among both males and females, the elevation among males in this census tract also reached statistical significance. Although kidney cancer was significantly higher among males in this area, this is consistent with the expected pattern of disease in the general population: kidney cancer is twice as common in males as it is in females (ACS 2001b).

Kidney cancer most often occurs in the fifth and sixth decades of life (50-70 year age group) (ACS 2001b). In Weymouth, individuals diagnosed with kidney cancer tended to be older than those in the general population. The average age of diagnosis was 67 years and more than half of all individuals diagnosed with kidney cancer during 1995-1998 were over the age of

70 at the time of their diagnosis. Similarly, the greatest increase in rates was seen among males in the 75-84 year age group. In CT 4221, the age distribution was closer to the expected pattern: the average age of diagnosis was 59 years and almost half of the individuals (44%) were diagnosed between the ages of 50 and 70 years.

2. Smoking Status

Cigarette smoking is the most important known risk factor for kidney cancer. Smoking increases the risk of developing kidney cancer by 30% to 100%. In both males and females, a statistically significant dose response relationship between smoking and this cancer has been observed. Approximately one-third of kidney cancers in men and one-quarter in women may be caused by cigarette smoking (ACS, 2001b).

Thirty-two percent of individuals diagnosed with kidney cancer in Weymouth between 1995 and 1998 reported being a current or former smoker at the time of diagnosis. However, almost half (45%) had unknown smoking status. This compares with 41% and 28% of individuals diagnosed in Massachusetts as a whole, respectively (see Figure 5). In Weymouth CT 4221, where a statistically significant elevation in the incidence of this cancer was observed during 1995-1998, three individuals were current or former smokers at the time of diagnosis, three were non-smokers, and two did not report smoking information.

3. Occupation

Environmental and occupational factors have also been associated with the development of kidney cancer. Some studies have shown an increased incidence of this cancer type among leather tanners, shoe workers, and workers exposed to asbestos. Exposure to cadmium is associated with an increased incidence of kidney cancer, particularly among men who smoke. In addition, workplace exposure to organic solvents, particularly trichloroethylene, may increase the risk of this cancer (ACS 2001b).

In Weymouth, one out of thirty-one individuals diagnosed with kidney cancer during 1995-1998 reported an occupation potentially associated with an increased risk of kidney cancer. Ten individuals (32%) had occupations listed as retired or unknown. In CT 4221, where a statistically significant increase in the incidence of kidney cancer was noted during this time

period, none of the individuals diagnosed reported occupations associated with the development of this cancer.

C. Non-Hodgkin's Lymphoma

1. Age and Gender Distribution

As noted previously, although the incidence of NHL was about as expected in Weymouth overall during 1995-1998, a statistically significant increase in this cancer type was observed among males in CT 4224 during this time period. The greater male to female ratio observed townwide and in CT 4224 was consistent with the established literature on this disease. NHL can occur at all ages, however, the median age at diagnosis is in the early 40s and the incidence of this disease generally increases with age (ACS 1998). Although the average age of diagnosis townwide was higher than expected (65 years), the trend of increasing incidence with increasing age was consistent with the age pattern for this cancer; 84% of those diagnosed during this time period were over the age of 50 years. In CT 4224, the average age of diagnosis was 62 years and the increase in incidence among males in this census tract can be primarily attributed to an increase in diagnoses among individuals in the 45-64 age group.

2. Occupation

Some occupations have been associated with an increased risk of developing NHL, such as occupations related to chemicals or agriculture. Farmers, herbicide and pesticide applicators, and grain workers appear to have the most increased risk. An elevated risk for NHL development has also been noted among fence workers, orchard workers, and meat workers (ACS 1998).

Among the forty-five individuals in Weymouth diagnosed with NHL during 1995-1998, no occupations associated with the development of this cancer were indicated. However, occupation was unknown or reported as retired for almost half (49%) of all cases. In CT 4224, where a statistically significant elevation in incidence among males was noted, 50% (n=4) of males reported their occupation as retired or unknown.

D. Pancreatic Cancer

1. Age and Gender Distribution

Although the incidence of pancreatic cancer was about as expected in Weymouth overall during 1995-1998, residents of CT 4221 experienced significantly more cases of pancreatic cancer than expected based on the state rate. Men are approximately 30% more likely to develop pancreatic cancer than are women (ACS 2000b). Gender-specific incidence rates in Weymouth and CT 4221 were consistent with the established pattern of this disease. Risk for this cancer increases with age; the majority of pancreatic cancer cases are diagnosed between age 60 and 80 (ACS 2000b). As expected, the average age of diagnosis in Weymouth was 74 years and the majority of cases (56%) were diagnosed between the ages of 60 and 80. In CT 4221, the average age of diagnosis was 63 years. Three out of the six individuals diagnosed in this CT were between the ages of 50 and 55.

2. Smoking Status

Besides age, the most consistent and only established risk factor for pancreatic cancer is cigarette smoking. According to the American Cancer Society, approximately 30% of all pancreatic cancer cases are thought to result directly from cigarette smoking (ACS 2000b). Studies have estimated that the risk of pancreatic cancer is two to six times greater in heavy smokers than in non-smokers (Anderson et al. 1996).

The incidence of pancreatic cancer in Weymouth during 1995-1998 was about as expected based on the state rate. However, incidence was significantly elevated in CT 4221 during this time period. In Weymouth overall, approximately 36% of individuals (n=9) diagnosed with pancreatic cancer were current or former smokers at the time of diagnosis. This compares to about 41% for the state of Massachusetts as a whole (see Figure 6). Review of smoking status information for individuals diagnosed with pancreatic cancer in CT 4221 revealed that half were non-smokers at the time of diagnosis and half were current or former smokers at the time of diagnosis. Moreover, all females were non-smokers while all males diagnosed were current or former smokers.

3. Occupation

Numerous occupations have been investigated for their potential role in the development of pancreatic cancer, but studies have not produced consistent results. Heavy exposure to certain pesticides (including DDT and its derivatives) may increase the risk of pancreatic cancer. Exposure to certain dyes and certain chemicals related to gasoline, in addition to asbestos and ionizing radiation, have also been associated with the development of pancreatic cancer in some studies, however, other studies have found no link between these agents and pancreatic cancer (ACS 2000b).

Occupational information reported to the MCR for individuals diagnosed with pancreatic cancer during 1995-1998 was listed as retired or unknown for 36% of cases (n=9). For the remaining individuals, the occupational information either indicated a job title not associated with known exposures to potential carcinogens or was not specific enough to determine whether the occupation may be associated with exposures that could increase the risk of pancreatic cancer. In CT 4221, where a statistically significant elevation in the incidence of pancreatic cancer was noted during this time period, occupation was reported as retired or unknown for one individual.

VI. ANALYSIS OF GEOGRAPHIC DISTRIBUTION OF CANCER INCIDENCE

In addition to determining census tract-specific incidence rates for each cancer type, a qualitative evaluation was conducted to determine whether any specific cancer type appeared to be concentrated in any of the four towns of Weymouth, Abington, Hingham, and Rockland or their census tracts during the time period evaluated in this report (i.e., 1995-1998). Place of residence at the time of diagnosis was mapped for all cancer types to assess any possible geographic concentration of cases. In addition, to address cancer concerns in relation to the SWNAS, this review also specifically focused on the geographic pattern of cancer cases in neighborhoods surrounding the base.

As previously mentioned, cancer is one word that describes many different diseases. Therefore, concentrations of cancers of different types in a particular geographic area are not indicative of an unusual or atypical distribution. For the purposes of this evaluation, the

geographic distribution of each cancer type was evaluated separately to determine whether an atypical pattern of any one type occurred. The geographic distributions of some specific cancer types were also evaluated together because they may have similar etiologies (i.e., leukemia and NHL in children). In addition, cancers that may be associated with specific environmental exposures of concern were also evaluated geographically to determine whether any atypical patterns of cases exist that may suggest an association with an environmental factor.

A. Geographic Distribution of Cancer in relation to SWNAS

Review of the geographic distribution of cancer in Weymouth, Abington, Hingham, and Rockland revealed no apparent spatial patterns at the neighborhood level that could not be attributed to factors such as areas of higher population density (e.g., the presence of multiunit complexes or nursing homes). For example, although statistically significant elevations of lung cancer were observed in Weymouth CTs 4222, 4223, and 4228 during 1995-1998, the distribution of cases within each of these census tracts seemed to coincide closely with the pattern of population in these areas. No one area within these census tracts displayed a geographic concentration of lung cancer cases.

Within the four towns, statistically significant elevations in the incidence of certain cancer types were observed in several census tracts surrounding the SWNAS during the 4-year time period 1995-1998. However, when the geographic distribution of these cancers were evaluated at the neighborhood level, the patterns of cases did not appear to be unusually clustered in areas close to the base. The incidence of lung cancer was significantly elevated in Weymouth CT 4222 and Rockland CT 5022, portions of which include the SWNAS property, however, the majority of cases were located in the more populated areas of these census tracts, farther away from the SWNAS. Although statistically significant elevations in the incidence of kidney cancer and pancreatic cancer were observed in Weymouth CT 4221 which abuts the SWNAS, none of the cases were unusually concentrated in any one area within this census tract.

B. Evaluation of Geographic Distribution Related to Other Community Cancer and Environmental Concerns

During the course of conducting the SWNAS investigation, the MDPH was also contacted by individuals in the towns of Weymouth and Hingham who had cancer concerns unrelated to the base. To address these specific concerns, the geographic distribution of cancer for these particular areas is described below. In addition, an evaluation of the geographic distribution of known hazardous release sites or 21E sites and each cancer type was conducted for all four towns.

One of the concerns was regarding cancer health effects potentially related to two salvage yards located near a neighborhood close to the border of CTs 4224 and 4225 in the town of Weymouth. Of the eight cancer types evaluated, the incidence of NHL was statistically significantly elevated among males in CT 4224 between the years 1995-1998. The geographic distribution of NHL cases closely matched the pattern of population in this area. Moreover, NHL cases were not concentrated in areas of salvage yards or in a pattern suggesting associations with the salvage yards. Some other types of cancers were diagnosed among residents in this area but they consisted of various types and they did not occur in a pattern suggesting a common factor, either environmental or non-environmental.

The MDPH was also contacted regarding a suspected elevation of cancer in the Mt. Vernon Road area located in CT 4226 in the town of Weymouth. None of the cancer types evaluated during the time period 1995-1998 were significantly elevated in this census tract. No unusual geographic concentration of cases was observed in the Mt. Vernon Road area for any of the cancer types evaluated.

The geographic distribution of cancer cases in the Weymouth Neck area was also reviewed for those cancer types evaluated that have been associated with exposure to lead and arsenic according to the literature (e.g., bladder cancer, kidney cancer, liver cancer, and lung cancer). As previously mentioned, the incidence of lung cancer was significantly elevated in CT 4228 where the Weymouth Neck Landfill is located. Again, review of the geographic distribution of cases did not reveal any unexpected concentrations or other spatial patterns in this area. Further, there were no unusual concentrations of bladder cancer, kidney cancer, or liver

cancer cases that were inconsistent with what would be expected based on population density in this area.

The MDPH was also contacted about a suspected high incidence of cancer in the area near Hersey Street located in Hingham CT 5011.02. Of the cancer types evaluated in the town of Hingham, there were no significant increases in incidence rates in this census tract during the 1995-1998 time period. Further, no cancer type was unusually concentrated in the area near Hersey Street.

The geographic distribution of each of the eight cancer types was examined relative to the locations of 21E sites mapped for Weymouth, Abington, Hingham, and Rockland. Based on this review there were no unusual geographic concentrations of cancer cases in relation to any of the 21E sites evaluated.

VII. DISCUSSION

With some exceptions, cancer incidence in Weymouth, Abington, Hingham, and Rockland during the time period 1995-1998 was approximately at or near the expected rates for the cancer types evaluated in this report. Statistically significant elevations in incidence were observed for lung cancer in the towns of Weymouth and Rockland as a whole. Significant elevations in incidence were also observed among residents in individual census tracts for some cancer types. These included lung cancer in Weymouth CTs 4222, 4223, and 4228, Abington CT 5202.02 (among males only), and Rockland CTs 5021 and 5022; kidney cancer in Weymouth CT 4221; NHL in Weymouth CT 4224 (among males); and pancreatic cancer in Weymouth CT 4221. However, a number of cancer types occurred less often than expected in the four towns or in individual census tracts during this time period (see Section IV. Results of Cancer Incidence Analysis and Tables 1 through 20).

Analysis of the geographic distribution of residences of individuals diagnosed during 1995-1998 did not reveal any atypical spatial patterns of cancer. Specifically, the distribution of cases seemed to coincide closely with the pattern of population in these towns. Further, although census tracts near the SWNAS displayed statistically significant elevations in lung cancer, no

unexpected concentrations of diagnoses were observed close to the SWNAS property or other hazardous environmental sites in this area.

Available risk factor information for each of the cancer types that demonstrated a statistically significant elevation during 1995-1998 was compared to known or established incidence trends to assess whether any unexpected patterns exist in Weymouth, Abington, Hingham, or Rockland. In general, trends observed in these towns were similar to those seen in the general population. For example, age is risk factors in many types of cancers including lung cancer, kidney cancer, NHL, and pancreatic cancer. The age distribution of diagnoses of these cancer types, which were significantly elevated in some towns or census tracts during 1995-1998, were generally consistent with disease patterns described in the epidemiological literature.

However, some findings regarding gender-specific incidence rates were somewhat unexpected. Specifically, while both males and females experienced significantly elevated rates of lung cancer town-wide in Weymouth and Rockland, females in both towns were diagnosed relatively more often than males. In the general population, incidence rates are higher among males than among females (ACS 2001a). One possible explanation for the trends seen in Weymouth and Rockland is that nationally, as well as in Massachusetts, incidence rates of lung cancer have declined among men in the last decade, while rates among women have continued to increase (ACS 2001a).

Lung cancer is the second most common type of cancer and the leading cause of cancer deaths among both men and women in the U.S. In 2001, almost 170,000 new cases will be diagnosed (ACS 2001a). Cigarette smoking is by far the most important risk factor in the development of lung cancer and the increasing lung cancer rates among females is largely due to the smoking habits of women in general. While smoking rates among men have decreased over the last 30 years, likely contributing to decreased rates of lung cancer, decreasing smoking patterns among women lag behind those of men (ACS 2001a). In Weymouth and Rockland, more than half of the individuals diagnosed with lung cancer during 1995-1998 were current or former smokers at the time of diagnosis. It is likely that smoking played some role in the development of lung or bronchus cancer in these individuals. However, because of the large number of cases with unknown smoking status (approximately 40% in each town), it is difficult

to fully assess the extent to which tobacco use influenced the rate of lung cancer in Weymouth and Rockland.

As noted earlier, workplace exposures to chemicals such as arsenic, asbestos, and radon, are also associated with an increased risk of lung cancer. Review of occupational data for individuals diagnosed with this cancer during 1995-1998 revealed that for the majority of individuals, job title information was not known, not specific, or indicated an occupation where exposures would not be likely. However, occupational exposures may have been important in the development of lung cancer in a small number of cases (e.g., 15 cases in Weymouth, 7 cases in Abington, and 3 cases in Rockland). Again, given the large number of individuals for whom occupational information was unknown or not specific, it is difficult to determine the role, if any, that workplace exposures played in the incidence of lung cancer in this region.

The distribution of histology type for diagnoses of lung cancer in Weymouth and Abington was different from that seen in the general population. The American Cancer Society estimates that approximately 40% of all lung cancers are adenocarcinomas, 30% are squamous cell carcinomas, 20% are small cell carcinomas, and 10% are large cell carcinomas (ACS 2000a). Rates in Massachusetts during 1995-1998 were very similar to those seen nationally. Further, trends in Rockland were consistent with this distribution pattern. However, in Weymouth, of the lung cancer diagnoses with specific histology classification, 35% were adenocarcinomas, 19% were squamous cell carcinomas, 20% were small cell carcinomas, and 23% were large cell carcinomas. Among males in Abington CT 5202.02, who experienced a statistically significant elevation in lung cancer, 40% were adenocarcinomas, 20% were squamous cell carcinomas, 10% were small cell carcinomas, and 30% were large cell carcinomas. Although smoking is associated with an increased risk of all types of lung cancer, it is most strongly associated with the development of small cell carcinoma and squamous cell carcinoma.

Although incidence rates for kidney cancer, NHL, and pancreatic cancer were significantly elevated in some Weymouth census tracts (e.g., CT 4221 and 4224), review of available risk factor information (e.g., age, gender, smoking status, and occupation) did not indicate any atypical patterns of disease based on trends in the general population. Similarly, a

review of the geographic distribution of individuals diagnosed with these cancers did not reveal any unexpected spatial patterns or other concentration of diagnoses. As noted earlier, the incidence of these cancer types townwide was about as expected. Results of the census tract-specific analysis should be interpreted with caution; due to the small number of cases of each cancer type, it is difficult to determine whether the observed elevations reflect true trends in the pattern of these cancers (e.g., true increases) in Weymouth CTs or are the result of random variation in cancer rates.

Based on the information reviewed in this evaluation, as well as environmental data reviewed for the SWNAS, it does not appear that environmental exposures played a major role in the incidence of cancer in Weymouth, Abington, Hingham, and Rockland during the 4-year time period 1995-1998. However, it is important to note that this evaluation cannot determine the exact cause (environmental or otherwise) of any one individual's cancer diagnosis.

VIII. LIMITATIONS

This assessment is an investigation that analyzes descriptive health outcome data for cancer to determine whether the pattern or occurrence of selected cancers is unusual. The purpose of this investigation is to evaluate the patterns of cancer in a geographical context in relation to available information about factors related to cancer (i.e., environmental factors) to see whether further investigation seems warranted. Information from descriptive analyses, which may suggest that a common etiology (or cause) is possible, can serve to identify areas where further public health actions may be warranted. Inherent limitations in this type of analysis and the available data make it impossible to determine the precise causal relationships or synergistic roles that may have played a part in the development of individual cancers in these communities. Also, this type of analysis cannot determine what may have caused any one individual's cancer. Cancers in general have a variety of risk factors known or suggested to be related to the etiology (cause) of the disease that could not be evaluated in this report. It is believed that many cancers are related largely to behavioral factors such as cigarette smoking, diet, and alcohol consumption. Other factors associated with cancer are socioeconomic status, heredity/genetics, race, and geography. It is beyond the scope of this report to determine the

causal relationship of these factors and the development of cancer or other health outcomes in Weymouth, Abington, Hingham, and Rockland.

In addition, the reader may want to compare one census tract's SIR with another, or compare an SIR for a cancer type in these town's with an SIR for a cancer type in another town. This is not an appropriate or meaningful comparison as the SIRs calculated here were based on one standard or comparison population, the state of Massachusetts. Small differences in the age distribution of a specific population are sufficient to affect some change in SIR values.

IX. CONCLUSIONS

- Of the eight cancer types evaluated in the communities of Weymouth, Abington, Hingham, and Rockland during 1995-1998, the majority occurred approximately at or near the expected rate. The exceptions included statistically significant elevations in the incidence of lung cancer in Weymouth and Rockland.

- When evaluated by census tract, the majority of cancer types evaluated in the four towns occurred approximately at or near the rates expected. However, significant elevations were observed among residents in individual census tracts for some cancer types. These included lung cancer in Weymouth CTs 4222, 4223, and 4228, Abington CT 5202.02 (among males only), and Rockland CTs 5021 and 5022; kidney cancer in Weymouth CT 4221; NHL in Weymouth CT 4224 (among males only); and pancreatic cancer in Weymouth CT 4221. A number of cancer types also occurred less often than expected.

- Review of the geographic distribution of cancer in Weymouth, Abington, Hingham, and Rockland revealed no apparent spatial patterns at the neighborhood level that could not be attributed to factors such as areas of higher population density (e.g., the presence of multiunit complexes or nursing homes). Further, although census tracts near the SWNAS displayed statistically significant elevations in lung cancer, no unexpected concentrations of diagnoses were observed close to the SWNAS property or other hazardous environmental sites in this area.

- Review of available risk factor information related to cancers that were elevated in the communities of Weymouth, Abington, Hingham, and Rockland suggests that cigarette smoking may have played a role in increased rates of cancers of the lung, kidney, and pancreas.

- The occupational information reviewed suggests that occupational exposures may have been a potential factor in the development of some individuals' cancers. However, information on occupation reported to the MCR is generally too limited to evaluate the actual role it may have played in areas where increased cancer rates were observed.

- An evaluation of the geographic distribution of cancer cases in relation to other environmental concerns in specific neighborhoods unrelated to the SWNAS did not reveal any unusual patterns of cases.

- Analysis of environmental and non-environmental risk factors as well as an evaluation of the geographic distribution of cases, did not reveal a clear pattern suggesting that environmental exposures from the SWNAS contributed to the incidence of cancer in Weymouth, Abington, Hingham, and Rockland during the 4-year time period 1995-1998. Moreover, the available data do not show a common pattern that would suggest that any single risk factor (environmental or otherwise) is likely to be responsible for the incidence of cancer in these four towns. Rather, a combination of factors such as smoking, diet, and exercise may be contributing to incidence rates in these towns.

X. RECOMMENDATIONS

- As a result of trends observed in the incidence of lung cancer, the MDPH plans to further investigate lung cancer in these communities in relation to individual length of residence, particularly among non-smokers, to determine whether a clearer pattern related to environmental or other risks for this cancer may emerge.

- Based on information regarding the incidence of lung cancer and smoking in Weymouth, Abington, and Rockland, the MDPH recommends that tobacco control efforts be targeted accordingly.

- The Boards of Health in Weymouth, Abington, Hingham, and Rockland should consider the results of this analysis in planning of prevention/intervention strategies to evaluate potential health impacts associated with environmental concerns in the future.

- Through the use of the Massachusetts Cancer Registry, MDPH will continue to monitor cancer incidence in the towns of Weymouth, Abington, Hingham, and Rockland.

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FIGURES

TABLES