

AN ASSESSMENT OF A CANCER MORTALITY SURVEY IN THREE  
TMI AREAS SELECTED BY LOCAL RESIDENTS

DIVISION OF EPIDEMIOLOGY RESEARCH  
PENNSYLVANIA DEPARTMENT OF HEALTH

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## I. BACKGROUND

The results of a health survey conducted by a group of local residents were made public on June 21, 1984, with the release of a document, Aamodt Motions for Investigation of Licensee's Reports of Radioactive Releases During the Initial Days of the TMI-2 Accident and Postponement of Restart Decision Pending Resolution of This Investigation.(1)

Three separate areas were selected for their survey. The door-to-door survey of the areas was conducted by a group of citizens who volunteered to interview local residents, but little information was provided in the report regarding quality control or the study design. One of the areas was reported to be six miles northwest of the plant and another, three and one-half miles to the southwest. The third area, seven miles northwest of the plant, was reportedly chosen because of its high elevation and clear view of the TMI plant. However, the specific locations of the three areas are not provided in the report.

The demographic and cancer mortality data in the report are very limited. No information regarding cancer site or dates of diagnosis and/or death is provided. According to the text of the report, however, the overall cancer mortality rate for the areas selected for the "five year period" since the accident is 5.2 to 6.5 times higher than expected.

Following its release, the Centers for Disease Control (CDC), United States Public Health Service, reviewed the document at the request of the U.S. Nuclear Regulatory Commission. In its

September 1984 response, CDC noted a number of epidemiologic deficiencies in the data presented and concluded that the survey did not present "convincing evidence of cancer incidence, cancer mortality, or adverse pregnancy outcome in TMI-area residents following the accident."

In the meantime, the Pennsylvania Department of Health, which also reviewed the document, obtained some additional summary survey data. This data permitted a more comprehensive evaluation of the data included in the document. This evaluation cast additional doubt on the accuracy and utility of the survey. It found not only a lack of information about the cancer deaths, but an actual difference in the numbers. In one case, for example, nine deaths were reported, but eight were included on summary sheets. Moreover, the only information reported for five of these eight deaths was as follows: "not interviewed--cancer--died."

Concurrent with its review of the available survey data, the Pennsylvania Department of Health analyzed cancer mortality data for four York County minor civil divisions in the vicinity of the three survey areas in question. These analyses did not indicate the existence of an apparent cancer problem, but critical evaluation of the allegations was not possible because the necessary detailed information, including the precise location of the survey areas, was not available. The original survey data compiled by local residents indicated there was a total of 20

cancer deaths in the three survey areas during the "five year period 1979-1984", (1) dates which actually cover a six-year period.

In November, 1984, the Pennsylvania Department of Health was requested by the Advisory Panel for Decontamination of TMI 2 to further evaluate cancer morbidity and mortality in the three areas. We were able to ascertain more information regarding the reported cancer cases by directly contacting those responsible for reporting the residents' survey results. The additional information they provided included the family names and the number of occupants in each household they surveyed, information on the streets and roads surveyed, and the general boundaries of the survey areas. However, the authors declined to provide other needed information, such as the age and sex of participants, health history, individual residential addresses, and length of residence, citing confidentiality as their reason.

The additional information did, however, enable the Pennsylvania Department of Health to initiate a more thorough assessment of cancer mortality in the same survey areas.

## II. METHODS

The assessment of mortality in the three survey areas was complicated by the fact that the areas had no precise geographic boundaries and, being primarily rural areas, street addresses were nonexistent. Fortunately, Area 2, the largest of the three areas, was included in a special 1979 TMI Census of Population which included all households within an approximate five-mile

radius of the nuclear facility. About one-half of Area 1, the second largest of the areas, also was included in the TMI Census. Only Area 3, which included fewer than 20 households was beyond the five-mile limit. Thus, information on the resident population at the time of the accident could be produced for the majority of the persons included in the subject survey areas. Information on the populations outside the TMI Census area was obtained from a school census conducted in 1979 by the West Shore School District and cross reference directories.

In order to use the TMI and school census data, however, it was first necessary for us to delineate precisely the boundaries of the subject survey areas. This required field visits to the three areas because (a) the Pennsylvania Department of Health was given family names only, and these generally for those households contacted by local interviewers, and (b) the readily available residence information from the TMI Census, particularly for persons residing in Newberry Township, did not provide street addresses which would have facilitated the delineation of the survey areas. During the field visits, housing unit counts were made, residents' names and Post Office Box numbers obtained, and maps developed to show area streets and the location of housing units. On the basis of information obtained during the repeated field trips by Health Department personnel, Survey Area 2 was redefined and expanded because it was clear that not all appropriate area streets were included in the original survey. The data obtained in the visits to the three survey areas were

checked against and supplemented by data from the TMI and school censuses, cross reference directories, death certificates, and Cancer Registry files. In addition, questionnaires were sent to physicians who treated area cancer decedents to obtain additional diagnostic information. These were followed up by telephone calls when necessary.

### III. RESULTS

#### A. DEMOGRAPHIC CHARACTERISTICS

##### 1. Minor Civil Divisions: MCDs

All three of the areas surveyed by local residents are located within York County minor civil divisions; Areas 1 and 3 in Fairview Township and Area 2 in Newberry Township. Both of these MCDs are situated to the west of the Susquehanna River. More specifically, Fairview Township is predominantly west-northwest of Three Mile Island (TMI), while Newberry Township extends to the north and south of TMI.

The populations of both townships, Newberry in particular, increased substantially during the decade of the 1970s, an important consideration in evaluating time trends in morbidity and mortality. The population of Newberry Township increased by 68.1 percent, from 5,978 in 1970 to 10,047 in 1980, while Fairview Township increased by 29.1 percent, from 9,278 to 11,941. The 1982 population estimates for Newberry and Fairview Townships are 10,279 and 12,337 respectively.

The median ages of these predominantly white populations (98.7 percent) were lower than the State median age of 32.1 years: Fairview Township, 30.4 years and Newberry Township, 27.8 years.

2. TMI Census Enumeration Districts: CEDs

Five TMI Census Enumeration Districts (CEDs) in Fairview and Newberry Townships generally correspond to the survey areas in question. They had a total population of 2,885 in 1979.

3. Survey Areas Selected by Local Residents

Survey Area 1, about 4.5 to 6 miles northwest of TMI in Fairview Township, consists primarily of households along a single rural road with a few housing units on connecting roads also being included. Thirty-five households and an estimated 118 persons were reported in the survey by local residents for Area 1 (TABLE 1). The Pennsylvania Department of Health estimates for Area 1, based on 1979 TMI and school census data supplemented by 1985 field visits, are 41 housing units and 140 persons (TABLE 2). Survey Area 3, also in Fairview Township, but about seven miles north-northwest of TMI, likewise consists of a single road. The count of households made by local residents and the estimate of total persons in Area 3 were 15 and 51, respectively (TABLE 1). The corresponding Pennsylvania Department of Health figures, based predominantly on

1979 school census data supplemented by field visits are 17 housing units and 75 residents (TABLE 2).

It was in Area 2 (Newberry Township), however, where the greatest discrepancies were found. During the course of field visits to the area, it became evident that (a) the stated boundaries of the area did not coincide with the area actually surveyed, and (b) there were a number of streets in the immediate area which presumably should have been included in the survey but which were not. Specifically, of about 14 streets/roads in the area which might have been surveyed by the residents' group, only four, which reportedly included 93 houses and an estimated 288 persons (TABLE 1), were stated to be in Area 2. There was at least one cancer death on each of the four streets selected by local residents in Survey Area 2, but none on the streets not selected for the survey. These no-cancer streets included 91 housing units with an estimated 325 persons in 1979. The Pennsylvania Department of Health estimates for Area 2, thus, included a total of 201 housing units and 673 persons (TABLE 2). These counts excluded housing units and persons not present at the time of the TMI accident. Specifically, there were five housing units on one street, three of which were included in the June 1979 TMI Census, but unoccupied at the time of the TMI accident (March, 1979), which were not included in our analysis.

B. CANCER MORTALITY IN THREE SELECTED AREAS

The citizens' group reported that its data showed cancer mortality in the three survey areas to be 5.2 to 6.5 times higher than expected. However, in view of (a) the results of the routine Pennsylvania Department of Health cancer mortality monitoring in the TMI area, (b) a special evaluation of cancer mortality data for the survey area MCDs, and (c) the obvious limitations of the survey conducted by local residents, such a contention seemed untenable. After proper adjustments were made for incorrect residences reported on death certificates, the observed number of cancer deaths for Fairview and Newberry Townships for the post-TMI period, 144, was remarkably close to the expected number (age-sex adjusted) of 142.0 (TABLE 3). Mortality data for 1984 were incomplete, thus they were not analyzed at the time our report was prepared.

Although the survey conducted by local residents resulted in a substantial undercount of the base population and a crude method, without adjustment for age-sex variations, of estimating expected cancer deaths was used, their overall expected number of cancer deaths in the three survey areas (4.9) for the "5-year" post-TMI period was not as different from the Department of Health's expected number (6.3) as might have been anticipated. The use of a rather high overall cancer death rate for Pennsylvania for 1979 as "standard", in comparison with the relatively

younger population of the survey areas partially compensated for an under-estimation of the number of area residents.

While the expected number of cancer deaths in the three survey areas was understated by the local residents, the observed numbers were overstated. First, the expected numbers presented by the residents' group are for a "five-year" (1979-83) period. The 20 originally reported deaths, presumably for the 1979-83 period, however, included two who died in 1984; these should have been excluded. Second, one of the decedents died in 1978, i.e., prior to the March 1979 accident at TMI, and another person who died of a cause other than cancer was apparently confused with a relative who died of cancer prior to the TMI accident. Third, two of the decedents were no longer residents of the area at the time of death, thus should not be included in this cross-sectional analysis. However, because this is a cross-sectional mortality study, two decedents who were not survey-area residents at the time of the TMI accident are included in this analysis.

In the course of reviewing death certificate data for the Fairview/Newberry Township area, we located one survey area decedent who had cancer at death, but who had not been previously reported by local residents. This decedent is included, as should be, in the TABLE 3 data compiled by the State Health Department.

The figures used by the Pennsylvania Department of Health and those used by the local residents' survey group regarding the observed number of cancer deaths differ at times. For example, four cancer deaths were reported in the residents' survey of Area 3; but our data (1979-83) show two. One of the four was the previously reported non-cancer decedent apparently confused with a relative; and the second was a 1984 death. While the residents' group claimed a 7.2 to 8.3 fold excess in cancer mortality for this particular area, our data show two deaths in comparison with the expected 0.5. Moreover, one of these two decedents was not a survey area resident at the time of the TMI accident.

According to our data, the age-sex adjusted (indirect method) expected number of cancer deaths for the modified, combined survey area was 6.3 for the 1979-83 period, as compared with 15 observed (TABLE 3). However, these 15 cancer deaths, as listed in TABLE 4 according to year of death and cancer site, include six decedents whose diagnosis was made before the accident; one decedent who was not a survey area resident at the time of the accident; one decedent who was diagnosed within months of the accident as having a cancer which usually has a long latency period; and two lung cancer decedents who were long-term heavy smokers.

While five cancer cases were diagnosed in 1981, it should be noted that (1) three and possibly four cases were also diagnosed in 1978, prior to the accident; and (2) two

of the five diagnosed in 1981 were long-term smokers who died of lung cancer. It should also be noted that bias which already was introduced in the initial selection of the three specific areas because of apparent knowledge of cancer by local residents remains. Thus, the results of subsequent statistical analyses based on such biased data are invalid.

The observed and expected numbers of cancer deaths for the five combined TMI Census Enumeration Districts (CEDs) within Fairview and Newberry Townships which encompass the three survey areas are 30 and 21.3 (TABLE 3). The mortality ratio (1.41) is within a range of random variation.

#### IV. DISCUSSION, EVALUATION AND CRITIQUE

Several deficiencies are inherent in the 1984 cancer survey conducted by local residents. These are summarized in the nine points which follow:

1. The study was based only on cancer mortality rather than cancer incidence data. Mortality data have limited value when causal relationships are to be established between environmental exposure and cancer. Many cancer patients live many years after initial diagnosis. Reliable morbidity data, such as case incidence, would have been much more useful for this type of investigation.
2. An insufficient latency period had elapsed since the accident to justify the conclusion reached in the survey. Most forms of malignancy have long latency

periods, depending upon the type of cancer and the nature of the environmental exposure. In some cases, as long as 20 to 30 years may be required before the cancer manifests itself. In the case of radiation-induced cancer, leukemia is known to have a relatively short latency with high dose exposure but, even in leukemia, the peak incidence may not be observed until five or six years after exposure. Furthermore, many such patients can survive a number of years following the initial diagnosis. Other forms of cancer induced by radiation may not be observable for 10 to 15 years or more after exposure. Thus, one should not expect to observe any significant increase in cancer within a few years, even if radiation doses were much higher than previously thought.

3. From the experience gained by observing the Japanese atomic bomb survivors and through other epidemiologic studies, certain specific forms of malignancies can be expected to occur following exposure to high-dose radiation. Therefore, one might look for such specific types of cancer as leukemia, in relation to radiation. When many different types of cancer are observed, as is the case with the reported cancer deaths, it suggests an absence of a single causal relationship.
4. The study conducted by the local residents made a conclusion that a particular cause and effect relationship had been found without ruling out other

possible causes. Cancer is a group of diseases that can be caused by one or more of a variety of environmental and genetic factors such as diet, tobacco, micro-organisms, radiation, food additives, occupational/industrial exposures, host susceptibility, etc. Because of the complexity of cancer etiology, one should not draw quick conclusions about cause and effect relationships. If higher mortality rates are found, it is tempting to attribute these to those potential causative agents that would seem to be most apparent in a given place or time. The radiation releases from TMI are a case in point. However, before one can make a responsible judgment about causation for a given form of cancer, it is necessary to search for and rule out other possible causes.

5. The expected numbers of cancer deaths calculated by the local residents were based only on total population figures and overall cancer death rates for the standard. They did not take into account either the age or sex distributions of the populations being studied or the fact that cancer death rates generally increase with age. Thus, if the distribution of the population under study is quite different from that of the standard, an expected number based on only total population and overall death rate may be totally inappropriate.
6. For the purpose of establishing a causal relationship between any chronic disease with long latency such as

cancer and radiation, cross-sectional mortality and morbidity data at a given time in a given population are not completely adequate because:

- (a) Some of the people originally exposed to the TMI related radiation have moved out of the area and some of them may have developed cancer or died elsewhere from it. These cases would be lost from cross-sectional studies, but they should be included.
  - (b) In contrast, cross-sectional population data do include a certain number of people who moved into the area after the accident but who may have developed cancer before moving into the area and died from it at the new address. Usually, these in-migrants are not identified in cross-sectional data, thus they are bound to be included in such studies, but they should not be.
  - (c) It would be more appropriate to conduct a long-term follow-up study of the originally exposed population (cohort) regardless of the current address.
7. Those who conduct any field investigation of this type should be aware that small area statistics are highly unstable and statistical significance tests applied to such data are difficult to interpret. When small community areas are considered, mortality and morbidity rates can fluctuate markedly from one area to another

and from one year to another without any substantive epidemiologic importance.

8. It has been amply demonstrated and documented<sup>(3)</sup> that "cancer clusters" are frequently observed in community settings such as in churches, schools, factories, or along certain streets. This is because cancer is a common disease in the United States, with the life-time incidence of one case per every four to five people. With such a high frequency, it is not at all difficult to observe apparent "clustering" depending upon how the geographic boundary is delineated or how the small area population at risk is identified and selected.
9. The most important and serious defect in the survey conducted by local residents is the rather obvious selection bias which was introduced in their data collection by the inclusion of only selected specific geographic areas (streets/roads), households, and individual residents in the survey. There is evidence that such selection was influenced by the pre-existing knowledge of cancer deaths. The statistical significance tests performed in any epidemiological studies are appropriate only if the selection of the study area (population) is uninfluenced by such bias. Otherwise, the results of such tests are invalid and cannot be accepted.

While the authors of this small area survey claimed that cancer mortality has markedly increased around TMI, and impli-

cated the 1979 nuclear accident at TMI as being responsible, the data presented in their survey do not support their conclusions for the reasons discussed in this critique. Furthermore, the comprehensive epidemiologic studies of cancer mortality and morbidity conducted by the Pennsylvania Department of Health do not provide evidence that cancer mortality has increased significantly around TMI. This would include the four selected downwind MCDs and the specific smaller areas within these York County MCDs where special in-depth analyses were performed.

## REFERENCES

(1) Aamodt, M.M. and Aamodt, N.O. Aamodt motions for investigation of licensee's reports of radioactive releases during the initial days of the TMI-2 accident and postponement of restart decision pending resolution of this investigation. Presented to United States Nuclear Regulatory Commission, June 21, 1984.

(2) National Center for Health Statistics: Advance Report, final mortality statistics, 1979. Monthly Vital Statistics Report, Vol. 31--No. 6, Supp. DHHS Pub. No. (PHS) 82-1120, Public Health Service, Hyattsville, MD. September 1982.

(3) Glass, A.G.; Hill, J.A.; and Miller, R.W. Significance of Leukemia Clusters. J. of Pediatrics 73, 1968.

**TABLE 1: ESTIMATED NUMBERS OF HOUSING UNITS AND POPULATIONS IN THREE AREAS  
(STREETS/ROADS) SELECTED BY LOCAL RESIDENTS FOR CANCER SURVEY AROUND TMI**

Survey Areas (Streets/Roads)	Housing Units	Population Estimates
Combined Area (1, 2 & 3)	143	457
Area 1	35	118
Area 2	83	288
Area 3	15	51

NOTES: Source of housing and resident data: Amodeo Motions for Investigation of Licensee's Reports of Radioactive Releases During the Initial Days of the TMI-2 Accident and Postponement of Restart Decision Resolution of this Investigation, June 21, 1984.

(TABLE 1 DATA ARE DISCUSSED ON PAGES 6 AND 7 OF THE TEXT.)

**TABLE 2: ESTIMATED NUMBERS OF HOUSING UNITS AND POPULATIONS IN THREE AREAS (STREETS/ROADS) SELECTED BY LOCAL RESIDENTS FOR CANCER SURVEY AROUND TMI, ADJUSTED BY PDOH FOR OMISSIONS IN INITIAL SURVEY**

Adjusted Survey Areas (Streets/Roads)	Estimated Housing Units	Population Estimates
Combined Areas (1, 2 & 3)	259	888
Area 1	41	140
Area 2	201 <sup>(a)</sup>	673 <sup>(a)</sup>
Area 3	17	75

NOTES: Sources of Pennsylvania Department of Health (PDOH) data: The Three Mile Island (TMI) Population Registry (1979 TMI Census) and/or a 1979 West Shore School District Census supplemented by field visits to the survey areas by PDOH's staff.

<sup>(a)</sup> Initial survey conducted by local residents included only 4 streets/roads, but did not include 10 other streets/roads in the same general area. There were no cancer deaths on any of these omitted streets/roads during the 1979-83 period. There were five housing units on one area street, three of which were included in the 1979 TMI Census, but unoccupied at the time of the TMI accident; they are not included in this Table.

[TABLE 2 DATA ARE DISCUSSED ON PAGES 6 AND 7 OF THE TEXT.]

**TABLE 3: POPULATION ESTIMATES AND OBSERVED AND EXPECTED NUMBERS OF AGE-SEX ADJUSTED  
CANCER DEATHS: SELECTED/ADJUSTED TMI AREAS, 1979-1983**

Geographic Areas	Population <sup>(a)</sup>	Cancer Deaths		Mortality Ratio {Obs./Exp.}
		Observed <sup>(b)</sup>	Expected <sup>(c)</sup>	
Fairview/Newberry Townships (2 MCDs)	21,988	144	142.0	1.01
TMI Census Districts (5 CEDs)	2,885	30	21.3	1.41
Adjusted Survey Areas (1, 2 & 3)	888	15	6.3	2.38*

NOTES: <sup>(a)</sup>Minor civil division (MCD) populations, 1980 U.S. Census of Population; Census Enumeration District (CED) populations, 1979 TMI Census; Areas (streets/roads) initially selected by local residents for cancer survey, which have been adjusted by State Health Department according to the 1979 TMI Census and 1979 School District Census.

<sup>(b)</sup>Observed number of cancer deaths, Pennsylvania Department of Health vital records. Numbers shown for MCDs may not match routinely reported numbers because of residence corrections. Observed numbers do not include two former residents of the Survey Areas who were not residents of either Fairview or Newberry Townships at the time of death. Conversely, two Survey Area residents who were not residents of the area at the time of the TMI accident but who were residents at the time of death are included.

<sup>(c)</sup>Expected numbers of cancer deaths for the post-TMI period (1979-1983) were based on estimates of the age-sex distribution of the respective populations and age-sex specific average annual cancer death rates for Pennsylvania, 1979-81 used as standard (Indirect Method of Standardization).

\*P<.01

(TABLE 3 DATA ARE DISCUSSED ON PAGES 8 - 11 OF THE TEXT.)

**TABLE 4: CANCER DEATHS BY SITE, YEAR OF DEATH, AND YEAR OF DIAGNOSIS: ADJUSTED SURVEY AREAS, 1979-83**

Year of Death	Cancer Site	Year of Diagnosis	Remarks
1979	Breast	1969	
1980	Leukemia	1976	
	Lymphoma, lower spine	1977-78	
	Colon	1979	
	Prostate	Unknown	
1981	Breast	1978	
	Prostate	1978	
	Melanoma, metastatic	1978	
	Ovary	Unknown	Death certificate: onset one year prior to death.
	Lung (oat cell)	1981	Decedent smoked 30 cigarettes per day for 15 years.
1982	Adrenal, NOS	1981	
	Multiple myeloma	1981	
	Lung	1981	Decedent smoked 30 cigarettes per day for 30 years.
	Metastatic (primary unknown)	1981	
	Leukemia	Unknown	Decedent was not a survey area resident at the time of the TMI accident.

NOTE: Sources of data include: death certificates, responses to a physician survey, and 1979 TMI Census information.

[TABLE 4 DATA ARE DISCUSSED ON PAGES 10 AND 11 OF THE TEXT.]



CANCER MORTALITY AND MORBIDITY (INCIDENCE) AROUND TMI

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Prologue and Summary

CANCER MORTALITY AND MORBIDITY (INCIDENCE) AROUND TMI

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More than six years have elapsed since the March 1979 accident at the Three Mile Island (TMI) nuclear facility. During this period, concerns about low level radiation as a possible cause of cancer have been a subject of considerable attention. These concerns have been heightened by a review of radiation dose assessment sponsored by the TMI Public Health Fund and a survey of cancer mortality by a group of local volunteers in selected communities near TMI.

The Pennsylvania Department of Health has conducted an epidemiological study to determine if there is evidence of unusual cancer mortality and morbidity in communities around TMI, and if so, to determine if the findings are consistent with what is currently known about cancer caused by radiation.

Cancer caused by radiation generally has a long latency period before diagnosis can be made (10 to 20 years or more). Even leukemia, which is known to have a relatively short latency period, is usually not detectable earlier than five years following radiation exposure.

The present study examines both cancer mortality (deaths) and morbidity (incidence, i.e., the number of newly diagnosed cancer cases) and the results presented include: (a) comparison of the observed and expected numbers of cancer deaths, (b) comparison of the observed and expected numbers of newly diagnosed cancer cases (incidence), and (c) followup of the incidence of cancer among specific groups of mothers and fetuses presumably exposed to radiation as a result of the TMI accident.

## ANALYSIS OF CANCER MORTALITY IN TMI AREAS:

Direct comparison of cancer rates before and after the TMI accident would have been desirable. However, such comparisons require adjustments for population changes and for the influences of the age-sex compositions of area populations under study. Because total and age-sex specific population data for the time prior to the accident are not available, such comparisons are not possible on a scientifically valid basis.

Under the circumstance, an observed vs. expected number method was used. The expected numbers of cancer deaths computed for the post-TMI period (1979-1983)<sup>a)</sup> are those which would have been anticipated, based on the 1980 population, if the communities under study had the same age-sex cancer mortality experience as Pennsylvania had during the 1979-80-81 period (average). The observed numbers of cancer deaths for the period prior to TMI (1974-1978) have been included in the study to provide some indication of whether or not unusually high or low cancer mortality may have occurred in areas surrounding TMI prior to the accident. It should be noted that in areas of population increase, the expected numbers for the pre-TMI period would tend to be "overestimates" while for the post-TMI period they would tend to be "underestimates."

a) For purposes of this report the post-TMI period is January 1, 1979 through December 31, 1983 and the pre-TMI period is January 1, 1974 through December 31, 1978.

The reader should also be aware that one may expect to see more cancer cases, living or deceased, in the post-TMI period regardless of the accident because of the following:

- \* General increase in cancer cases in Pennsylvania and elsewhere.
- \* Population increases over time in many areas under study.
- \* Better cancer reporting system.
- \* Improved diagnostic techniques and opportunities.
- \* Cancer patients now live longer than previously.
- \* Increased longevity (older persons are more susceptible to cancer).

#### ANALYSIS OF CANCER MORBIDITY IN TMI AREAS:

In addition to analyzing the number of deaths due to cancer, the Department also analyzed cancer morbidity (newly diagnosed cases or incidence) in the TMI area. Incidence data are more useful than mortality data in assessing possible connections between radiation exposure and cancer.

It is well established that there is a long latency period between radiation exposure and the diagnosis of cancer. There is an even longer time lag between exposure and death from cancer. Accordingly, if radiation exposure from TMI had resulted in any increase in the number of cancers, it will be observed in the incidence data long before being observed in mortality data.

Cancer morbidity (incidence) data used in this study were obtained from the Pennsylvania Cancer Registry which became operational in July 1982 for the TMI area. The data gap from the time of the accident through June 1982 is not considered serious in view of the fact, as previously noted, that radiogenic cancers

are not expected to be observable within a few years post exposure. These missing years, however, were well covered by the Department of Health's comprehensive analysis of the mortality data (see Summary of Major Findings).

ANALYSIS OF CANCER INCIDENCE AMONG MOTHERS AND FETUSES PRESUMABLY EXPOSED TO RADIATION FROM TMI:

The method of analyzing cancer incidence data in a given population as of a given year does not consider the fact that, since the accident, some individuals have moved out while others have moved into the study areas. In order to take this migration factor into account, a special analysis was conducted involving nearly 4,000 pregnant women living in the TMI area at the time of the accident.

Subsequent to the accident, pregnant women residing within 10 miles of TMI were entered into the Pennsylvania Department of Health Mother/Child Registry. The mothers and children they were carrying at that time have been monitored systematically to determine if they have experienced an unusual increase in cancer incidence.

The analysis of cancer morbidity (incidence) among this group living in the area at the time of the accident complements the Department's analysis of cancer mortality data. The results of this special analysis are discussed in the Summary of Major Findings.

ADDITIONAL CONSIDERATIONS/LIMITATIONS:

1. CORRECTION OF ERRORS IN PLACE OF RESIDENCE

For selected small geographic areas, particularly those located north, northwest, and west of the TMI facility (down-wind during the early period of the accident), a special effort was made in this study to insure the accuracy of the place of residence reported for each of the identified cancer cases. Such care is necessary because mailing addresses are often incorrectly reported as residential addresses on mortality and cancer records.

2. FLUCTUATING STATISTICS FOR SMALL AREAS

One should be aware that it is difficult to draw conclusions based on small area statistics because of the inherent variability in the data and thus the increased probability of error in making inferences. In fact, mortality and morbidity rates for small areas can and do fluctuate markedly from one area to another and from time to time within the same area. This normal fluctuation may create false impressions among lay observers about the importance of different rates from one time period to another or between one area and another.

### 3. CANCER CLUSTERS

"Cancer Clusters" are frequently observed in community settings such as churches, schools, factories, or along certain streets. This is because cancer is a common disease in the United States, with a life-time incidence of one case for every four to five people. With such a high frequency, it is not difficult to observe apparent "clustering" depending upon how a geographic boundary is delineated or how the small area population at risk is identified and selected.

### 4. CAUSE AND EFFECT RELATIONSHIPS

It is tempting to attribute high cancer death rates or an increase in cancer morbidity to those potential causative agents that would seem to be most apparent in a given place or time. The radiation releases from TMI are a case in point. However, cancer can be caused by one or more of a variety of environmental and genetic factors such as: diet, tobacco, micro-organisms, radiation, food additives, occupational/industrial exposures, host susceptibility, etc. Because of the complexity of cancer etiology, one should not draw quick conclusions about cause and effect relationships.

SUMMARY OF MAJOR FINDINGS:

1. The results of mortality analyses provide no evidence that cancer mortality in the TMI area was significantly different from expectation after the accident. On the contrary, the area covering a 20-mile radius from the plant was found to have had fewer cancer deaths than expected during the 5-year period post-TMI (7,924 observed versus 8,177 expected). Analyses of data for several smaller geographic areas, regardless of distance and direction from the TMI facility, also showed no observed numbers significantly higher than expected. While in some instances the observed numbers of cancer deaths post-TMI were higher than expected, others were lower than expected, a sign of random variation.
2. TMI area cancer mortality data were also analyzed according to eight major anatomical site classifications. While recognizing the presence of random variations, there were no significant increases in any cancer sites, including leukemia and other radiogenic cancers. The nine leukemia deaths reported during the period January 1, 1979 through December 31, 1983 in four selected MCDs (Fairview and Newberry Townships and Goldsboro and York Haven Boroughs), compared to the three leukemia deaths of the pre-TMI period

might be viewed by lay persons to be of importance.

However, neither nine nor three deaths were significantly different from the expected number of six for the area. It should be noted that one of the nine patients actually died before the accident and, of the remaining, two were diagnosed as having leukemia prior to the accident (in 1976 and 1978). In still another case, the available clinical data suggest that the apparent onset of leukemia was noted by a physician well before the accident.

3. In addition to analyzing deaths caused by cancers, the Department also analyzed the number of newly diagnosed cases of cancer. According to Pennsylvania Cancer Registry data for the July 1982-June 1984 period, there is no indication that the number of newly diagnosed cases of cancer was significantly higher than expected for the four MCDs. The differences between the observed and expected numbers of cases for these areas could have occurred by chance alone. Furthermore, the total number of radiogenic cancer cases observed in the four communities was not significantly greater than expected. In particular, leukemia, the most likely cancer that could be detected as early as 5 to 6 years following exposure to radiation, was diagnosed in only two area residents while approximately four cases might have been expected. Again, these differences are not statistically significant.

4. The TMI Mother/Child Registry includes a study group of nearly 4,000 pregnant women who delivered between March 28, 1979 and March 27, 1980. These women were residing within a 10 mile radius of TMI and most of them were pregnant at the time of the accident. This Registry is updated continuously and is linked to the Pennsylvania Cancer Registry file. During the July 1982-December 1983 period, four of the 3,582 mothers (most of whom were residing in 14 southcentral Pennsylvania counties) were diagnosed as having cancer. Based on the national cancer registry data for females in the 10-44 year age group, 3.9 mothers might have been expected to be so diagnosed during this time period. Of the mothers' children, two were diagnosed with cancer, while one case was expected. Neither of these differences is statistically significant. Thus, available information based on mothers and children presumably exposed to TMI radiation gives no indication of a significant increase in cancer incidence at this time.

CONCLUSIONS:

The results of our epidemiologic study, including both mortality and morbidity data, do not present evidence of an increased risk of developing cancer by local residents living near the TMI nuclear facility.

In view of the known long latency period from exposure to a cancer-causing agent and the development of cancer, however, and the persistent dispute over the amount of radiation releases from the damaged TMI nuclear reactor, it is prudent to continue epidemiologic surveillance of cancer around TMI. The Pennsylvania Department of Health established the mechanism for such an effort shortly after the 1979 accident and several long-term followup studies of those who presumably were exposed to TMI radiation are in progress.

SUMMARY OF EVALUATION OF THE AAMODT SURVEY:

The results of a health survey conducted by a group of local residents (Aamodt survey) were made public on June 21, 1984. The Aamodt survey concluded that cancer mortality has markedly increased around TMI and implicated the 1979 nuclear accident at Three Mile Island (TMI) as being responsible. It covered three separate, small geographic areas northwest of the TMI facility, but provided little information regarding the survey design or methodology. The demographic and cancer mortality data in the survey were very limited and incomplete.

Following its release, the Centers for Disease Control (CDC), U.S. Public Health Service, reviewed the Aamodt document at the request of the U.S. Nuclear Regulatory Commission. CDC identified a number of epidemiologic deficiencies in the data presented and concluded that the Aamodt survey does not present "convincing evidence of increased cancer incidence; increased cancer mortality; or adverse pregnancy outcome in the TMI-area residents following the accident." In November, 1984, the Pennsylvania Department of Health was requested by the Advisory Panel for Decontamination of TMI Unit 2 to further evaluate cancer data presented in the Aamodt Survey.

The Division of Epidemiology Research of the Pennsylvania Department of Health was able to ascertain some additional information regarding the reported cancer cases. This enabled the Department to conduct a more thorough assessment of the Aamodt survey of cancer mortality.

A re-analysis of the data originally presented in the Aamodt survey, as well as additional data for the same general area procured by the State Health Department, does not support the claim that the TMI accident caused an increase in cancer deaths. A number of methodological defects was noted in their survey. These defects and related comments are summarized as follows:

1. The most important and serious defect in the Aamodt survey is the selection bias which was introduced early in data collection by the inclusion of only specific geographic areas (streets), households and individual residents while ignoring others equally qualified for inclusion. More specifically, there is evidence that such selection was influenced by the pre-existing knowledge of cancer deaths, i.e., only those streets where cancer deaths were known to be present were chosen, ignoring other streets in the same area where no cancer deaths were reported. Because of this selection bias, the results of the Aamodt analyses are invalid.
2. The Aamodt survey claims a causal relationship between radiation resulting from the March, 1979 accident at TMI and cancer in the areas they surveyed. This claim, however, is based on mortality data, which, by themselves, are of limited value in establishing such a relationship. The

Aamodt survey provides very little information regarding essential cancer incidence data.

3. The Aamodt survey differed with the concept of latency in radiogenic cancer. Yet, leukemia is probably the only cancer for which one reasonably could expect to see an increased incidence within five or six years post-TMI (even if the disputed doses of radiation releases were in fact high enough to cause it). Other forms of radiogenic cancers may not be observable for at least 10 to 20 years or more after the initial exposure to high doses of radiation.
4. Existing epidemiologic studies indicate that certain specific forms of cancer are more likely to occur following exposure to high-dose radiation. When many different types of cancer are observed, as is the case with the Aamodts' reported cancer deaths, it suggests an absence of a single causal relationship.
5. Age and sex distributions of the local populations under study are important factors to consider when evaluating cancer mortality. The Aamodts' survey did not take these sensitive factors into account.

6. Unless supplemented by other data, cross-sectional mortality data are not adequate for establishing a causal relationship between cancer and TMI radiation because many people have moved out of and into the area since the accident. The former residents should be included, and the newcomers excluded in any scientific attempt to determine whether there is a connection between cancer mortality and the accident at TMI. The Aamodt survey did not address this problem.
  
7. The expected numbers of cancer deaths presented in the Aamodt survey are for a five-year period. The 20 "actual cancer deaths" reported by the Aamodts, however, include persons who died during a five year ten and a half month time period - a discrepancy, which given the limited population survey could have had a significant impact on their claimed death rate.
  
8. The Aamodt survey attributed an alleged increase in cancer mortality to the TMI accident. Of the 20 originally reported deaths, one died before the accident in 1978; one who died of a cause other than cancer was apparently confused with a relative who died of cancer prior to the accident; six were diagnosed as having cancer prior to the accident; and two were long-term heavy smokers who died of lung cancer. The remainder represented a variety of cancers normally found in any population group.

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## CANCER MORTALITY AND MORBIDITY (INCIDENCE) AROUND TMI

### I. INTRODUCTION

More than six years have elapsed since the March 28, 1979 accident at the Three Mile Island (TMI) nuclear power plant. Since the accident, concerns about the potential impact of radioactive substance releases on cancer incidence have been a subject of considerable attention. These concerns have been fueled by a recent review of radiation dose assessment conducted at the request of the TMI Public Health Fund and a survey of cancer mortality carried out by a group of citizens who focused on sections of communities near TMI. (1)

Government reports published earlier of radioactive substance releases and population exposures following the accident indicated that the radiation exposure of TMI area populations was very small and that future health effects would be minimal. With respect to the long-term health effect, it was projected that the number of cancer cases and genetic abnormalities over the lifetime of the some 2,000,000 persons living within 50 miles of the plant would be too small to be detectable. (2)

The purposes of the present study are to determine if there is sufficient epidemiologic evidence to indicate that cancer mortality and morbidity in communities around TMI show abnormal patterns regardless of the level of radiation releases, and that any substantial excess cancer cases, if observed, are consistent with the existing theory of radiation carcinogenesis.

The Pennsylvania Department of Health monitors cancer mortality for the 2,580 minor civil divisions (MCDs) within the State and conducts epidemiologic investigations of potential problem areas. Since the 1979 nuclear accident, the TMI area has been the subject of more intensive monitoring for several reasons including, (a) the continuing health concerns of area residents, (b) a general widespread interest in the situation, and (c) official requests by the Advisory Panel for Decontamination of TMI Unit 2 and the TMI Public Health Fund Advisory Group for further evaluation of cancer mortality and morbidity in certain TMI area communities investigated by local residents.

Now that the minimum latency periods for certain forms of cancer, such as leukemia, might have been reached, it is reasonable to consider possible long-term health effects of the accident, particularly the incidence of cancer in the area. Furthermore, it was only recently that the cancer incidence data necessary for an acceptable assessment of cancer problems in the area, became available from the Pennsylvania Cancer Registry which was instituted in South Central Pennsylvania in July, 1982.

The present study covered both cancer mortality and morbidity and the results presented include the following aspects:

- (a) comparison of the observed and expected numbers of cancer deaths,
- (b) comparison of the observed and expected numbers of newly diagnosed cancer cases, and
- (c) assessment of the followup incidence (newly diagnosed cases) of cancer within a defined population (cohort) presumably exposed to the TMI accident

radiation. Considered for the cohort analysis at this time are pregnant women and their fetuses who were residing within the ten-mile area at the time of the accident for whom accurate cancer incidence data have been made available.

## II. METHODS AND MATERIALS

The routine monitoring of cancer mortality in the TMI area has focused on all 35 minor civil divisions (MCDs) within ten miles of TMI.

The data used in monitoring cancer mortality in MCDs in the TMI area include: (a) enumerated MCD populations by age, sex, and race from decennial United States censuses of population; (b) intercensal and postcensal population estimates (total populations only) developed by the Pennsylvania Department of Health and other governmental agencies; and (c) cancer mortality data by age, sex, race and site from the State Health Data Center, Pennsylvania Department of Health, which is responsible for the state vital statistics registration system.

The time periods covered in this mortality study include a five-year pre-TMI period (1974-78), and a five-year post-TMI period (1979-83).<sup>a)</sup> Death rates (such as number of deaths per 100,000 population) are not presented for individual geographic areas because, when based on very small populations, as several are, single deaths can result in rates that cannot be reasonably compared with normative rates based on large populations.

a) For purposes of this report the pre-TMI period is January 1, 1974 through December 31, 1978 and the post-TMI period is January 1, 1979 through December 31, 1983.

Instead, "expected" or theoretical numbers of deaths that would be expected under normal conditions were computed for comparison with the observed numbers of deaths in each MCD. These include expected numbers for eight major cancer categories. The expected numbers of cancer deaths are those which would have been expected if the communities under study had the same age-sex-specific cancer mortality experiences as Pennsylvania as a whole during the 1979-81 period. More specifically, the expected numbers of cancer deaths are those which would have been expected if each age-sex population group in the communities under study had the same cancer mortality experiences as did the Pennsylvania population in that age-sex group between 1979 and 1981, and if the community's population remained the same in size (and in age-sex distribution) as it was at the time of the census in 1980. It is important that the expected numbers be computed in this manner because cancer death rates vary according to age and sex. The age-sex-specific population data needed to compute expected numbers of deaths specifically for the 1974-78 and 1979-83 periods were not available for the study populations. Thus, period-specific expected numbers of deaths could not be computed.

Cancer morbidity data for a two-year period (July 1982-June 1984) have recently become available for 14 counties in South Central Pennsylvania, including the TMI areas. As in the mortality analysis, the expected numbers of new cancer cases were computed on the basis of 1980 U.S. Census population data and on normative cancer incidence data (1978-1981) from the

Surveillance, Epidemiology and End Results (SEER) program of the National Cancer Institute. SEER data are used as the "standard" because Pennsylvania Cancer Registry data are not yet available for the State as a whole.

Population data developed from the special 1979 census, which included all households within an approximate five-mile radius of TMI, are also available for use in special investigations. These data permit the assessment of cancer morbidity and mortality in Census Enumeration Districts (CEDs), smaller areas within each minor civil division under study.

These special census data have been supplemented by population data from the 1979 school census in certain minor civil divisions. While school census data do not provide the detailed information available from the special TMI Census, the information provided proved to be extremely valuable when the areas of interest lie beyond the five-mile limit of the TMI Census.

In order to utilize data from the TMI Census for studying areas which do not conform to the Census Enumeration Districts (CEDs), field visits were necessary to determine the specific geographic boundaries of interest. This is particularly true when rural areas are involved and street addresses are not available.

Mortality studies and investigations conducted in Pennsylvania, which are residence-specific, are complicated by the frequent incorrect reporting of actual residence on vital records. This problem, of minor significance at the county level, can, in many instances, be one of the most important

factors to be considered in evaluating the mortality and morbidity rates for specific MCDs. The problem, which tends to result in artificially inflated rates for cities and boroughs and reduced rates for townships, stems from a frequent confusion of mailing address, by the persons providing information, with actual place of residence. Since post offices are usually located in cities or boroughs through which all mails are delivered, individuals associate mailing address with place of residence and report it as the place of residence on vital records. The ascertainment and correction of incorrect residence information, although difficult and time consuming, is necessary in the assessment of health problems in small areas.

The statistical significance of the differences between observed and expected cancer morbidity and mortality was assessed by computing standardized mortality and morbidity ratios (SMRs) and testing for significant departures from unity using the Poisson model.

As previously stated, the expected numbers of cancer deaths are based on the Pennsylvania cancer mortality experience, 1979-81, by age and sex, and the distribution (age-sex) of the study populations at the time of the 1980 Census of Population. Thus, the expected numbers of cancer deaths, based on normative data for the 1979-81 period can more appropriately be compared with observed numbers for the post-TMI period than for the pre-TMI period. The observed numbers of cancer deaths for the pre-TMI period are provided for reference purposes; however, differences between the pre- and post-TMI observed figures should

not automatically be attributed to TMI. As a matter of fact, the observed numbers for the pre-TMI period are likely to be lower than the expected numbers. In contrast, the observed numbers for the post-TMI period are likely to be higher than the expected numbers for the following reasons:

- The population in many of the areas under study increased substantially over this time period.
- There is a continuing general increase in cancer mortality in Pennsylvania and elsewhere.
- Diagnostic techniques and opportunities are improving.
- The population is aging and with age comes an increase in cancer incidence and, ultimately, mortality.

The expected numbers of new cancer cases (incidence) were based on incidence data by cancer site, age, and sex from the Surveillance, Epidemiology and End Results (SEER) program (1978-81) of the National Cancer Institute and population data from the 1980 census. Since the observed numbers of new cancer cases in the study populations are for a later period, July 1982--June 1984, caution again must be exercised in interpreting the data. Factors such as population growth or decline; improved cancer reporting systems; improved diagnostic techniques and opportunities; and aging populations, as well as actual changes in cancer incidence can have an impact on the results.

### III. RESULTS

#### A. GENERAL POPULATION CHARACTERISTICS

The TMI ten-mile area which includes 35 minor civil divisions and portions of five counties (Cumberland,

Dauphin, Lancaster, Lebanon and York) had an enumerated population of 289,930 in 1980. The TMI five-mile area, with a population of 64,897 in 1980 includes 13 minor civil divisions in three counties (Dauphin, Lancaster, and York).

The population of the TMI ten-mile area increased by 7.3 percent from 270,306 in 1970 to 289,930 in 1980 (the population of Pennsylvania increased by 0.6 percent). The population in the five-mile area, however, increased by 31.3 percent, from 49,410 to 64,897, while the population in the five to nine mile band increased by only 1.9 percent; from 220,896 to 225,033. Only two of the 13 minor civil divisions in the five-mile area lost population during the decade and these were relatively minor decreases in small boroughs (Royalton and Goldsboro). The populations of seven of the 13 minor civil divisions increased by more than 25 percent. The population of East Manchester Township increased by 105.4 percent, from 1,735 to 3,564, while Newberry Township's population increased by 68.1 percent, from 5,978 in 1970 to 10,047 in 1980. The population of seven of the 22 minor civil divisions in the five to nine mile area decreased between 1970 and 1980 (six were boroughs, the other was Harrisburg City) but seven municipalities experienced population increases of 25 percent or more. One, Conewago Township, increased by 119.8 percent, from 1,124 to 2,471. Lewisberry Borough experienced the greatest relative population decrease, 36.9 percent (from 490 to 309), but Harrisburg City, whose

population decreased by 21.7 percent, had the greatest absolute decline, 14,797 (from 68,061 to 53,264). The population of the five to nine mile area, exclusive of Harrisburg, increased by 12.4 percent between 1970 and 1980; with Harrisburg, the increase was only 1.9 percent.

In 1980, the median ages of the populations of the 35 minor civil divisions within ten miles of TMI ranged from 27.3 years for Conewago Township to 40.0 years for Paxtang Borough. Both are in Dauphin County. The median ages of the populations of ten of the 13 minor civil divisions in the five-mile TMI area and 17 of the 22 in the five to nine mile area increased between 1970 and 1980. Since cancer morbidity and mortality generally increase with age, it might be expected that certain increases in cancer morbidity and mortality during the decade of the 1970's would be associated with the aging of the population.

In 1970, 25,822 or 9.6 percent of the 270,306 residents of the TMI ten-mile area were nonwhite. By 1980, the number had increased to 33,627; the percentage to 11.6. Of the 33,627 nonwhites in the area, 25,074 (74.6 percent) resided in the City of Harrisburg; 2,079 (6.2 percent) in Lower Paxton Township; 1,833 (5.5 percent) in Steelton Borough; 1,619 (4.8 percent) in Swatara Township; 598 (1.8 percent) in Derry Township; and 571 (1.7 percent) in Middletown Borough. Thus, only about five percent of the nonwhite population resided in the other 29 TMI ten-mile

area communities. More than 47 percent of the population of Harrisburg City and 28 percent of the population of Steelton Borough were nonwhite in 1980. The only other communities in the area with nonwhite populations in excess of five percent were Swatara Township (8.6 percent), Lower Paxton Township (6.0 percent), and Middletown Borough (5.6 percent). All are located in Dauphin County.

B. CANCER MORTALITY

1. Overall Cancer Mortality by Minor Civil Division (MCD): 20-Mile Radius

The monitoring of cancer mortality in the TMI area by the Pennsylvania Department of Health, as previously stated, focuses on 35 minor civil divisions (MCDs) within ten miles of the nuclear facility, but periodically includes communities in a 20-mile area. This monitoring includes an annual comparison of observed and expected numbers of cancer deaths, total and selected cancer sites, in individual and grouped MCDs.

TABLE 1 shows the numbers of MCDs, the populations, and the observed and expected average annual numbers of cancer deaths for Pennsylvania and geographic areas at specified distances from TMI during a pre-TMI five-year period (1974-1978) and a post-TMI five-year period (1979-1983). The grouped MCD data by distance from TMI provide no indication of excess cancer mortality in geographic areas up to 20 miles

distant from TMI. The similarity between the observed and expected numbers of deaths, particularly for the post-TMI period, is remarkable. The observed numbers for the pre-TMI period are somewhat lower than the expected numbers but are of no particular significance. The observed average annual number of cancer deaths in the 10-19 mile ring for the post-TMI (1979-1983) period was lower than expected, and the observed and expected numbers for the 5-9 mile band and the five-mile radius areas were quite similar.

While the average annual number of cancer deaths among Pennsylvania residents increased by 8.5 percent from the 1974-78 period to the 1979-83 period, increases such as this are not limited to Pennsylvania. For example, the average annual number of cancer deaths of the United States increased by 12.1 percent during the same time periods. Such increases in the actual numbers of cancer in recent years are a reflection of many factors, including environmental carcinogens in addition to size and characteristics, particularly aging, of the population. The potential influence of the various cancer causing agents, however, are not accounted for in the observed-expected methodology used in this study.

## 2. Site-Specific Cancer Mortality: Ten-Mile Radius

TMI ten-mile area cancer mortality data for eight major cancer site classifications are presented in

TABLE 2. The specified cancer sites are: buccal cavity and pharynx; digestive organs and peritoneum; respiratory system; bone, connective tissue, skin and breast; genitourinary system; other and unspecified sites; leukemia; and other lymphatic and hematopoietic tissue. The variations from expectation, higher or lower, in these site-specific data are nominal for both time periods under study and have no particular epidemiologic importance.

3. Overall Cancer Mortality by Direction from TMI:  
Minor Civil Divisions

It has been alleged that, because of the wind direction at the time of the major radioactivity release from TMI, cancer mortality has increased in the population to the northwest (downwind) of the facility.

TABLE 3 shows cancer mortality data for TMI minor civil divisions grouped according to general direction quadrants from TMI. For each quadrant, the observed average annual numbers of cancer deaths for both the pre-TMI and post-TMI periods approximate the expected numbers. The average annual numbers of deaths for Goldsboro and Highspire Boroughs are higher than expected both before and after the accident. On the other hand, the average numbers of deaths for other communities, such as Londonderry, West Donegal, Conewago, Newberry, Fairview, and Lower Swatara, are lower than expected both before and after the

accident. Such variations in mortality are commonly observed when the population bases under study are relatively small.

4. Four Selected Communities: Downwind from TMI

Following the release of results of the health survey conducted by local citizens, which reportedly showed excess cancer mortality in selected areas within York County, available cancer mortality data for four area minor civil divisions were reviewed to determine if there was any evidence of a cancer mortality problem in these survey areas. Using 1979 TMI Population Census data, the actual place of residence of each post-TMI cancer decedent was determined. Presented in TABLE 4 are residence-corrected overall cancer mortality data pertaining to Fairview and Newberry Townships and Goldsboro and York Haven Boroughs for the post-TMI period. As shown in this table, the observed average annual number of cancer deaths in each MCD was remarkably close to expectation when necessary corrections were made on residential addresses. The observed average annual number of deaths for Goldsboro Borough was 1.0 and the expected number was 0.9, while the respective observed and expected numbers for York Haven Borough were 1.0 and 1.2. An annual average of 16.6 deaths was observed in Fairview Township, and

16.5 was expected. In Newberry Township, an average of 12.2 deaths per year was reported, while 11.9 was expected.

It was of further interest to examine how overall cancer mortality fluctuated each year within these four selected communities. TABLE 5 shows the actual number of resident cancer deaths for the selected communities for each of the five years, beginning with 1979. These numbers appear to reflect random-like variations in cancer mortality.

TABLE 6, which provides data for the combined population of the same four MCD area according to cancer site, includes grouped data for both the pre-TMI and post-TMI periods. As shown in this table, the site-specific number of cancer deaths generally approximate expectation within the limits of random variation. The numbers of site-specific deaths, even for an entire five-year period, are sometimes very small and one should be aware that one or two deaths, more or less, can have a marked effect on mortality ratios, but be of no particular significance.

The fact that nine leukemia deaths were reported during the five-year post-TMI period in the four selected MCDs, compared to three leukemia deaths in the pre-TMI period, might appear to be of importance. However, neither nine nor three deaths are significantly

different from the expected number of six for the area. It should be noted that one of the nine patients actually died before the accident, and two others were diagnosed as having leukemia prior to the accident (in 1976 and 1978), and consequently, these deaths cannot be attributed to TMI. In still another case, the available clinical data suggest that the apparent onset of leukemia was noted by a physician well before the accident.

5. TMI Census Enumeration Districts (CED): Downwind from TMI

The smallest geographic entities in the TMI area which can be studied with a reasonable degree of precision (in a statistical sense) are the Census Enumeration Districts (CEDs) delineated in the special 1979 TMI Census which covered the entire population residing within approximately five miles of TMI. There are 15 CEDs in Fairview and Newberry Townships, the downwind minor civil divisions of immediate concern. Only two of these CEDs are in Fairview Township, the other 13 are in Newberry Township. TABLE 7 presents population data and average annual observed and expected numbers of cancer deaths for the post-TMI (1979-1983) period for these small geographic areas. The CEDs are grouped to show data for the two townships according to the directional quadrants in which they

lie. The observed and expected average annual numbers of cancer deaths for all 15 CEDs combined are quite comparable (10.8 observed and 11.6 expected). Similarly, the deviations in the figures for the Northwest (7 CEDs) and Southwest (8 CEDs) quadrants are small and negligible. The mortality ratio for the Newberry Township CEDs in each of the two quadrants is 0.85; that is, observed mortality was less than expected. The mortality ratio for the two Fairview Township CEDs, which had a combined population of only 710 residents, was 1.80 (nine deaths observed, an estimated five expected). None of these ratios is indicative of a significant departure from expectation.

In summary, the data analyzed thus far provide no indication that cancer mortality in TMI area minor civil divisions, including much smaller areas within them, differed significantly from expectation during the five years following the March, 1979 accident at TMI.

B. CANCER MORBIDITY: INCIDENCE

Population-based cancer incidence data were not available for Pennsylvania communities prior to July 1, 1982. It was then that the Pennsylvania Cancer Registry became operational in South Central Pennsylvania, which includes the TMI area. While the Cancer Registry can now provide

morbidity data, there is a data gap from the time of the accident, March, 1979, through June, 1982. However, this data gap may not be considered serious in view of the fact that radiogenic cancers are not expected to be observable within a few years post exposure. Even leukemia, which is known to have a short latency period, is not likely to develop until at least five to six years following the initial exposure. Since six years have passed, early Registry data should be examined for possible new cases of cancer.

The use of Pennsylvania Cancer Registry data in epidemiologic investigations is relatively new. However, cancer incidence data for the four MCDs (Fairview and Newberry Townships and Goldsboro and York Haven Boroughs) were made available for special analysis.

The results of the special analyses, which include the period July 1, 1982 through June 30, 1984, are presented in TABLES 8, 9, and 10. The expected numbers of new cancer cases for this period are those which would have been expected if each age-sex population group in the communities under study had the same cancer incidence as did the SEER program population in that age-sex group during the years 1978-81, and if the community's population remained the same in size (and age-sex distribution) as it was at the time of the 1980 census. In no instance did the observed numbers of newly diagnosed cancer cases shown in these tables significantly exceed the expected numbers,

i.e., the differences between the observed and expected numbers could have occurred by chance alone. Specifically, the observed number of newly diagnosed cancer cases among residents of the combined four MCD area during this two-year post-TMI period was 133 as compared with 121.4 expected (TABLE 8). The observed number of new cases was less than expected for Fairview Township (61 observed and 65.6 expected) and there was virtually no difference between the observed and expected numbers for Goldsboro Borough (4 observed and 3.9 expected). The observed and expected numbers of newly diagnosed cancer cases for York Haven Borough were 8 and 4.5, respectively, while the respective numbers for Newberry Township were 58 observed and 47.8 expected. Again, these differences in the incidence of cancer are within the limits of random variation and not statistically significant at the 5 percent level. The exact place of residence of two cases could not be determined but they are included in the area total.

TABLE 9 shows, for the same July, 1982 through June, 1984 period, observed and expected numbers of cancer cases for 19 primary cancer sites (organ systems first affected) among residents of the total four minor civil division area and Fairview and Newberry Townships, combined and separately. The number of cancer cases of specific sites among residents of Goldsboro and York Haven Boroughs are shown in the "NOTES" section of the table. The expected

numbers are not presented for these two boroughs because the numbers for specific primary cancer sites are too small for meaningful comparison. Of 19 different cancer sites considered, the observed numbers for the entire four minor civil division area were lower than expected for 11 sites, whereas the observed numbers were higher than expected for eight others. Among these eight cancer sites, the relative differences between observed and expected were nominal and could be demonstrated in any set of random numbers subjected to multiple tests of significance. Similarly, the observed numbers for Fairview Township were lower than expected for 10 cancer sites and higher for nine others while for Newberry Township the observed numbers were higher for 12 sites and lower for seven others. Some of the differences were very small and none was significantly different from expectation. The occurrence of specific cancers among residents of Goldsboro and York Haven also appears to be randomly distributed. The 12 newly diagnosed cancer cases in these two communities include cancers of eight different primary sites. The only cancer for which more than one new case was reported in either of these two boroughs was breast cancer. Three York Haven women were diagnosed as having breast cancer during the two year period; this was not significantly more than expected.

An additional analysis was made of ten specific radiogenic cancers (TABLE 10). These are cancers, such

as leukemia, which are more susceptible to the injurious action of radiation. For purposes of this report, the following cancers were considered (although there is still some disagreement regarding degree of radiogenicity of certain of these): esophagus, stomach, colon, pancreas, lung, breast (female), thyroid, non-Hodgkin's lymphomas, multiple myeloma, and leukemia. The number of such cancers that would have been expected to be diagnosed among residents of the four subject minor civil divisions during the two-year period July 1982-June 1984 is 64.2; 70 cases were actually diagnosed. Twenty-six residents of Newberry Township were diagnosed as having these cancers; 25 were expected. The respective observed and expected figures for Fairview Township were 36 and 34.9. Goldsboro and York Haven Boroughs are too small in their populations for the computation of meaningful expected numbers of new cancers by specific sites but overall, seven were observed and about four to five were expected. None of these differences was statistically significant. These data do not provide any consistent indication of a possible radiation-related cancer problem. According to the existing literature, leukemia is the most likely cancer to be detectable five to six years following exposure to high dose radiation. Two leukemia cases were diagnosed in the four minor civil division area and three to four were expected. There was one case each in Fairview and Newberry Townships, but none in Goldsboro or York Haven Boroughs.

For some other forms of radiogenic cancer, more cases were reported than expected (e.g., colon, breast and non-Hodgkin's lymphomas) but for others there were fewer.

As already stated, these data are not indicative of a radiation related cancer problem in the area. Although the post-TMI observed number of newly identified cancer cases (133) is somewhat higher than the expected number (121.4) and although the observed number of radiogenic cancer cases (70) is somewhat higher than the expected number (64.2):

- none of the differences, overall or for specific minor civil divisions or specific cancer sites, is statistically significant at the five percent level;
- leukemia, the type of cancer most apt to show any abnormal pattern the earliest, had in fact fewer cases observed than expected;
- there are several reasons why the observed numbers are apt to be higher than the expected numbers, including general increases in cancer, population growth, better diagnostic techniques, improved cancer reporting, and an aging population.

D. TMI MOTHER/CHILD REGISTRY: COHORT FOLLOWUP

The Mother/Child Registry includes a study group of nearly 4,000 pregnant women who delivered between March 28, 1979 and March 27, 1980. These women resided in the TMI

ten-mile communities and were pregnant at the time of the accident or they became pregnant within a few months of the accident. The Mother/Child Registry also includes a comparison (control) cohort of nearly 4,000 pregnant women who delivered one year after the study cohort, between March 28, 1980 and March 27, 1981. The Registry is updated continuously to insure current information for each mother and child registrant on a number of variables for use in a variety of followup studies. Linkages are being established with the Pennsylvania Cancer Registry, the Pennsylvania Mortality File, the National Death Index, and out-of-state cancer registries, to identify those registrants who have developed cancer since the 1979 accident.

During the period July 1, 1982 through December 31, 1983, four of the 3,582 mothers in the study group, most of whom resided in 14 South Central Pennsylvania counties, were diagnosed as having cancer. Based on data from the Surveillance, Epidemiology, and End Results (SEER) program (1973-1977) for females in the 10-44 year age group, 3.9 mothers might have been expected to be so diagnosed during this time period. The primary cancer sites of these four patients were two colon, one brain, and one skin (trunk).

During this same period, two of the study children under five years of age were diagnosed as having cancer; about one case would have been expected on the basis of the SEER data; this small difference can occur by chance alone.

#### IV. SUMMARY AND CONCLUSIONS

More than six years after the 1979 accident at TMI, both cancer mortality and morbidity were examined. Comprehensive analyses of the available data included comparisons of the observed numbers of cancer with the expected numbers for a series of geographic areas, from a 20-mile radius down to small Census Enumeration Districts around TMI. Because of the potential importance of wind direction and radioactive plume dispersion during the early days of the accident, data also were analyzed with emphasis on the northwest and southwest quadrants. Also considered were the distribution by cancer sites for both living and deceased patients, as well as possible predilection for any radiogenic malignancies within expected latency periods. Furthermore, the incidence of newly diagnosed cases of cancer was evaluated among those women who were pregnant at the time of the accident and among their offspring.

While cancer mortality data are useful for certain purposes, they are severely limited when the time gap between exposure and observation point is shorter than the time gap between initial diagnosis and death. In contrast, incidence data are far more appropriate in assessing possible linkage between environmental risk exposure and carcinogenesis. The most effective method to be used in such an investigation is the prospective cohort followup study of the population actually exposed to the specific environmental risk under study.

The results of our epidemiologic study, including both mortality and morbidity data as well as cohort followup analysis, do not provide evidence of increased cancer risks to residents near the TMI nuclear facility.

In view of the known long latency of carcinogenesis and the persistent dispute over the amount of radioactive releases from the damaged TMI nuclear reactor, it is prudent to continue epidemiologic surveillance around TMI. The Pennsylvania Department of Health established the mechanism for such an effort shortly after the 1979 accident and several long-term followup studies are already in progress.

## REFERENCES

(1) Aamodt, M.M. and Aamodt, N.O. Aamodt motions for investigation of licensee's reports of radioactive releases during the initial days of the TMI-2 accident and postponement of restart decision pending resolution of this investigation. Presented to United States Nuclear Regulatory Commission, June 21, 1984.

(2) Ad Hoc Population Dose Assessment Group: Population dose and health impact of the accident at the Three Mile Island nuclear station. U.S. Government Printing Office, Washington, D.C., 1979, p.3.

**TABLE 1: NUMBER OF MINOR CIVIL DIVISIONS, POPULATION (1980), OBSERVED AND EXPECTED NUMBERS OF RESIDENT CANCER DEATHS, PENNSYLVANIA AND GEOGRAPHIC AREAS SELECTED DISTANCES FROM THREE MILE ISLAND (TMI), 1974-78 AND 1979-83**

Geographic Area	Number of Minor Civil Divisions	Population 1980 <sup>(1)</sup>	Five Year Total Number of Cancer Deaths			Average Annual Number of Cancer Deaths			Mortality Ratio [Observed/Expected]	
			Expected <sup>(2)</sup>	Observed <sup>(3)</sup>		Expected <sup>(2)</sup>	Observed <sup>(3)</sup>		1974-78	1979-83
				1974-78	1979-83		1974-78	1979-83		
Pennsylvania	2,500	11,863,895	129,122	120,581	130,873	25,824.3	24,118.2	26,174.8	0.93	1.01
<b>TMI Areas</b>										
20 Mile Radius	129	798,807	8,177	7,163	7,924	1,635.4	1,432.8	1,584.8	0.88	0.97
[10-19 Mile Band]	[94]	[508,877]	[5,268]	[4,374]	[5,032]	[1,053.7]	[874.8]	[1,008.4]	[0.83]	[0.88]
10-Mile Radius	35	289,930	2,809	2,789	2,892	581.7	657.8	578.4	0.98	0.99
[5-9 Mile Band]	[22]	[225,033]	[2,348]	[2,275]	[2,360]	[469.8]	[455.0]	[472.0]	[0.97]	[1.01]
5 Mile Radius	13	64,897	581	514	532	112.1	102.8	108.4	0.92	0.85

NOTES: (1) Enumerated populations, 1980 United States Census of Population.

(2) Expected numbers of cancer deaths based on the age-sex distribution of the respective populations, 1980 U.S. Census of Population, and average annual age-sex specific cancer death rates, Pennsylvania, 1979-81.

(3) Source of observed numbers of deaths; State Health Data Center, Pennsylvania Department of Health. These data are not corrected for incorrect residence reporting on death certificates.

[TABLE 1 DATA ARE DISCUSSED ON PAGES 10 AND 11 OF THE TEXT.]

**TABLE 2: OBSERVED AND EXPECTED AVERAGE ANNUAL NUMBERS OF CANCER DEATHS BY SITE: THI TEN-MILE AREA, 1974-78 AND 1979-83**

Cancer Site (Ninth Revision, International Classification of Diseases)	Code Number	Average Annual Number of Cancer Deaths			Mortality Ratio [Observed/Expected]	
		Expected <sup>(1)</sup>	Observed <sup>(2)</sup>		1974-78	1979-83
			1974-78	1979-83		
All Sites	140-208	581.7	557.8	578.4	0.96	0.99
Buccal Cavity and Pharynx	140-149	10.8	11.2	11.0	1.04	1.02
Digestive Organs and Peritoneum	150-159	165.5	146.2	155.6	0.88	0.94
Respiratory and Intrathoracic Organs	160-165	140.6	129.4	133.0	0.92	0.95
Bone, Connective Tissue, Skin & Breast	170-175	66.1	64.8	73.2	0.98	1.11
Genitourinary Organs	179-189	85.7	85.6	90.4	1.00	1.05
Other and Unspecified Sites	190-199	64.7	68.4	64.2	1.06	0.99
Leukemia	204-208	21.5	17.0	22.4	0.79	1.04
Other Lymphatic & Hematopoietic Tissue	200-203	29.5	35.2	28.6	1.19	0.97

NOTES: (1) Expected numbers of cancer deaths based on the age-sex distributions of THI Ten-Mile Area minor civil division populations, 1980 U.S. Census of Population, and average annual age-sex specific cancer death rates, Pennsylvania, 1979-81. The expected average annual number of deaths for cancer of all sites (581.7) does not equal the summation of expected deaths for specific sites (584.4) because the all sites total was computed on the basis of summary population data (by age-sex) for the entire THI Ten-Mile Area, as was done for other areas in Table 1, while the expected numbers for specific sites were obtained by summing the expected numbers for each of the 35 minor civil divisions in the area.

(2) Source of observed numbers of deaths; State Health Data Center, Pennsylvania Department of Health. These data are not corrected for incorrect residence reporting on death certificates.

[TABLE 2 DATA ARE DISCUSSED ON PAGES 11 AND 12 OF THE TEXT.]

**TABLE 3: OBSERVED AND EXPECTED AVERAGE ANNUAL NUMBER OF RESIDENT CANCER DEATHS FOR TMI AREA MINOR CIVIL DIVISIONS BY GENERAL DIRECTION FROM TMI, 1974-78 AND 1979-83**

General Direction from TMI/Minor Civil Division	Population 1980(1)	Average Annual Number of Cancer Deaths			Mortality Ratio [Observed/Expected]	
		Expected(2)	Observed(3)		1974-78	1979-83
			1974-78	1979-83		
<b>TMI Area MCDs</b>	<b>64,897</b>	<b>112.1</b>	<b>102.8</b>	<b>106.4</b>	<b>0.92</b>	<b>0.95</b>
<b>Northeast Quadrant</b>	<b>16,241</b>	<b>31.1</b>	<b>30.8</b>	<b>30.8</b>	<b>0.99</b>	<b>0.99</b>
Londonderry T. (Dauphin Co.)	5,138	7.5	6.4	7.4	0.85	0.98
Middletown B. (Dauphin Co.)	10,122	21.9	22.4	21.8	1.02	1.00
Royalton B. (Dauphin Co.)	981	1.7	2.0	1.6	1.18	0.94
<b>Southeast Quadrant</b>	<b>11,481</b>	<b>27.9</b>	<b>24.0</b>	<b>27.4</b>	<b>0.86</b>	<b>0.98</b>
Conoy T. (Lancaster Co.)	2,309	3.7	3.8	3.8	1.03	1.03
West Donegal T. (Lancaster Co.)	4,862	16.4	12.6	14.8	0.77	0.90
East Manchester T. (York Co.)	3,564	6.6	5.4	7.8	0.82	1.18
York Haven B. (York Co.)	746	1.2	2.2	1.0	1.83	0.83
<b>Southwest Quadrant</b>						
Conewago T. (York Co.)	4,979	7.5	6.2	5.4	0.83	0.72
<b>Southwest/Northwest Quadrants</b>						
Newberry T. (York Co.)	10,047	11.9	11.6	11.4	0.97	0.96
<b>Northwest Quadrant</b>	<b>22,149</b>	<b>33.8</b>	<b>30.2</b>	<b>31.4</b>	<b>0.89</b>	<b>0.93</b>
Fairview T. (York Co.)	11,941	16.5	11.4	16.2	0.69	0.98
Goldsboro B. (York Co.)	477	0.9	1.6	2.0	1.78	2.22
Highspire B. (Dauphin Co.)	2,959	5.9	8.0	6.8	1.36	1.15
Lower Swatara T. (Dauphin Co.)	6,772	10.5	9.2	6.4	0.88	0.61

NOTES: (1) Enumerated populations, 1980 United States Census of Population.

(2) Expected numbers of cancer deaths based on the age-sex distribution of the respective populations, 1980 U.S. Census of Population, and average annual age-sex specific cancer death rates, Pennsylvania, 1979-81.

(3) Source of observed numbers of deaths; State Health Data Center, Pennsylvania Department of Health. These data are not corrected for incorrect residence reporting on death certificates.

(TABLE 3 DATA ARE DISCUSSED ON PAGES 12 AND 13 OF THE TEXT.)

**TABLE 4: POPULATION AND OBSERVED AND EXPECTED AVERAGE ANNUAL NUMBERS OF CANCER DEATHS; FOUR TMI AREA MINOR CIVIL DIVISIONS (FAIRVIEW AND NEWBERRY TOWNSHIPS AND GOLDSBORO AND YORK HAVEN BOROUGHS), 1979-83**

Minor Civil Divisions (MCDs)	Population <sup>(1)</sup>	Average Annual Number of Cancer Deaths		Mortality Ratio [Observed/Expected]
		Observed <sup>(2)</sup>	Expected <sup>(3)</sup>	
Four Minor Civil Division Total	23,211	30.8	30.5	1.01
Fairview/Newberry Townships	21,988	28.8	28.4	1.01
Fairview Township	11,941	16.6	16.5	1.01
Newberry Township	10,047	12.2	11.9	1.03
Goldsboro/York Haven Boroughs	1,223	2.0	2.1	0.95
Goldsboro Borough	477	1.0	0.9	1.11
York Haven Borough	746	1.0	1.2	0.83

NOTES: (1) Enumerated populations, 1980 United States Census of Population.

(2) Observed numbers of cancer deaths obtained from death certificates provided by the State Health Data Center, Pennsylvania Department of Health. Numbers shown for specific MCDs may not match routinely reported numbers because of corrections of residence reported on death certificates.

(3) Expected numbers of cancer deaths based on age-sex distributions of the respective populations, 1980 U.S. Census of Population, and age-sex specific cancer death rates for Pennsylvania, 1979-81.

[TABLE 4 DATA ARE DISCUSSED ON PAGES 13 AND 14 OF THE TEXT.]

**TABLE 5: POPULATION AND OBSERVED AND EXPECTED NUMBERS OF CANCER DEATHS BY YEAR:  
CERTAIN TRI AREA MINOR CIVIL DIVISIONS, 1979-83**

Minor Civil Divisions (MCDs)	Population <sup>(1)</sup>	Observed <sup>(2)</sup> Annual Number of Cancer Deaths					Expected Number of Cancer Deaths Per Year <sup>(3)</sup>
		1979	1980	1981	1982	1983	
Four Minor Civil Division Total	23,211	22	33	30	36	33	30.5
Fairview/Newberry Townships	21,988	22	29	28	34	31	28.4
Fairview Township	11,941	10	21	13	19	20	16.5
Newberry Township	10,047	12	8	15	15	11	11.9
Goldsboro/York Haven Boroughs	1,223	—	4	2	2	2	2.1
Goldsboro Borough	477	—	2	1	1	1	0.9
Yorkhaven Borough	746	—	2	1	1	1	1.2

NOTES: (1) Enumerated populations, 1980 United States Census of Population.

(2) Observed numbers of cancer deaths obtained from death certificates provided by the State Health Data Center, Pennsylvania Department of Health. Numbers shown for specific MCDs may not match routinely reported numbers because of corrections of residence reported on death certificates.

(3) Expected numbers of cancer deaths based on age-sex distributions of the respective populations, 1980 U.S. Census of Population, and age-sex specific cancer death rates for Pennsylvania, 1979-81.

(TABLE 5 DATA ARE DISCUSSED ON PAGE 14 OF THE TEXT.)

**TABLE 6: OBSERVED AND EXPECTED AVERAGE ANNUAL NUMBERS OF CANCER DEATHS BY SITE IN A SELECTED FOUR MINOR CIVIL DIVISION AREA (FAIRVIEW TOWNSHIP, GOLDSBORO BOROUGH, NEWBERRY TOWNSHIP, YORK HAVEN BOROUGH), 1974-78 AND 1979-83**

Cancer Site (Ninth Revision, International Classification of Diseases)	Code Number	Average Annual Number of Cancer Deaths			Mortality Ratio [Observed/Expected]	
		Expected <sup>(1)</sup>	Observed <sup>(2)</sup>		1974-78	1979-83
			1974-78	1979-83		
All Sites	140-208	30.5	26.8	30.8	0.88	1.01
Buccal Cavity and Pharynx	140-149	0.6	0.8	0.4	1.33	0.67
Digestive Organs and Peritoneum	150-159	8.2	5.8	7.2	0.71	0.88
Respiratory and Intrathoracic Organs	160-165	7.9	5.8	6.4	0.73	0.81
Bone, Connective Tissue, Skin & Breast	170-175	3.6	4.2	4.0	1.17	1.11
Genitourinary Organs	179-189	4.2	4.0	4.2	0.95	1.00
Other and Unspecified Sites	190-199	3.4	3.4	4.4	1.00	1.29
Leukemia	204-208	1.2	0.6	1.8	0.50	1.50
Other Lymphatic & Hematopoietic Tissue	200-203	1.6	2.2	2.4	1.38	1.50

NOTES: (1) Expected numbers of cancer deaths based on the age-sex distribution of the respective populations, 1980 U.S. Census of Population, and average annual age-sex specific cancer death rates, Pennsylvania, 1979-81.

(2) Source of observed numbers of deaths; State Health Data Center, Pennsylvania Department of Health. The 1974-78 data are not corrected for incorrect residence reporting on death certificates; the 1979-83 data are corrected.

[TABLE 6 DATA ARE DISCUSSED ON PAGES 14 AND 15 OF THE TEXT.]

**TABLE 7: POPULATION AND OBSERVED AND EXPECTED AVERAGE ANNUAL NUMBERS OF CANCER DEATHS FOR FAIRVIEW AND NEWBERRY TOWNSHIP CENSUS ENUMERATION DISTRICTS WITHIN FIVE MILES OF THI BY GENERAL DIRECTION FROM THI, 1979-83**

Census Enumeration Districts (CEDs)/ General Direction from THI	Population 1979(1)	Average Annual Number of Cancer Deaths		Mortality Ratio [Observed/Expected]
		Observed(2)	Expected(3)	
Newberry/Fairview Township CEDs in THI Five Mile Area	8,118	10.8	11.6	0.93
Northwest Quadrant	3,075	4.0	3.6	1.11
Fairview Township (2 CEDs)	710	1.8	1.0	1.80
Newberry Township (5 CEDs)	2,365	2.2	2.6	0.85
Southwest Quadrant	5,043	6.8	8.0	0.85
Newberry Township (8 CEDs)	5,043	6.8	8.0	0.85

NOTES: (1) Enumerated populations, 1980 United States Census of Population.

(2) Observed numbers of cancer deaths obtained from death certificates provided by the State Health Data Center, Pennsylvania Department of Health. Incorrect residence information on death certificates has been corrected.

(3) Expected numbers of cancer deaths based on age-sex distributions of the respective populations, 1980 U.S. Census of Population, and age-sex specific cancer death rates for Pennsylvania, 1979-81.

[TABLE 7 DATA ARE DISCUSSED ON PAGES 15 AND 16 OF THE TEXT.]

**TABLE B: POPULATION AND OBSERVED AND EXPECTED NUMBERS OF DIAGNOSED CANCER CASES:  
FOUR TRI AREA CIVIL DIVISIONS, FAIRVIEW AND NEWBERRY TOWNSHIPS AND  
GOLDSBORO AND YORK HAVEN BOROUGHS, JULY 1982 - JUNE 1984**

Minor Civil Divisions (MCDs)	Population <sup>(1)</sup>	New Cancer Cases		Ratio [Observed/Expected]
		Observed <sup>(2)</sup>	Expected <sup>(3)</sup>	
Minor Civil Division Total	23,211	133	121.4	1.10
Fairview/Newberry Townships	21,988	119	113.4	1.05
Fairview Township	11,941	61	65.6	0.93
Newberry Township	10,047	58	47.8	1.21
Goldsboro/York Haven Boroughs	1,223	12	8.0	1.50
Goldsboro Borough	477	4	3.9	1.03
York Haven Borough	746	8	4.5	1.78
Town	—	2	—	—

NOTES: (1) Enumerated populations, 1980 United States Census of Population.

(2) Observed numbers of diagnosed cancer cases, Pennsylvania Cancer Registry, Pennsylvania Department of Health. Incorrect residence information on Cancer Registry Report Forms has been corrected.

(3) Expected numbers of cancer cases based on the age-sex distributions of the respective populations and age-sex specific incidence rates from the Surveillance, Epidemiology, and End Results (SEER) program, 1978-81.

(TABLE B DATA ARE DISCUSSED ON PAGES 17 AND 18 OF THE TEXT.)

**TABLE B: OBSERVED AND EXPECTED NUMBERS OF DIAGNOSED CANCER CASES BY PRIMARY SITE<sup>1</sup> IN A SELECTED FOUR MINOR CIVIL DIVISION AREA<sup>1</sup> WITH SEPARATE DATA FOR FAIRVIEW AND NEWBERRY TOWNSHIPS, JULY 1982 - JUNE 1984**

Primary Site	All Areas <sup>1</sup>			Fairview/Newberry Twp.			Fairview Township			Newberry Township		
	Obs. <sup>2</sup>	Exp. <sup>3</sup>	Ratio [Obs./Exp.]	Obs. <sup>2</sup>	Exp. <sup>3</sup>	Ratio [Obs./Exp.]	Obs. <sup>2</sup>	Exp. <sup>3</sup>	Ratio [Obs./Exp.]	Obs. <sup>2</sup>	Exp. <sup>3</sup>	Ratio [Obs./Exp.]
All Sites	133	121.4	1.10	119	113.4	1.05	61	65.8	0.93	58	47.8	1.21
Buccal Cavity and Pharynx	4	4.4	0.91	3	4.1	0.73	2	2.4	0.83	1	1.7	0.59
Stomach	2	3.0	0.67	2	2.8	0.71	1	1.8	0.63	1	1.2	0.83
Colon	18	11.4	1.58	15	10.5	1.43	8	6.1	1.31	7	4.4	1.59
Rectum	8	5.0	1.60	8	4.7	1.70	3	2.8	1.07	5	1.9	2.63
Esophagus	1	3.0	0.33	1	2.7	0.37	1	1.8	0.63	-	1.1	-
Larynx	5	1.8	2.78	4	1.7	2.35	2	1.0	2.00	2	0.7	2.86
Lung and Bronchus	17	18.8	0.90	17	17.7	0.96	8	10.2	0.78	9	7.5	1.20
Melanoma of Skin	3	3.6	0.83	3	3.4	0.88	-	2.0	-	3	1.4	2.14
Breast (Female)	21	16.8	1.27	17	15.8	1.09	11	9.2	1.20	6	6.4	0.94
Corpus Uteri	-	2.4	-	-	2.2	-	-	1.3	-	-	0.9	-
Corpus Uteri	4	4.6	0.87	3	4.3	0.70	-	2.5	-	3	1.8	1.67
Ovary	4	2.6	1.54	4	2.5	1.60	2	1.5	1.33	2	1.0	2.00
Prostate Gland	6	10.2	0.59	6	9.5	0.63	1	5.4	0.18	5	4.1	1.22
Urinary Bladder	4	5.0	0.80	3	4.7	0.84	3	2.7	1.11	-	2.0	-
Kidney and Renal Pelvis	5	2.4	2.08	5	2.3	2.17	3	1.4	2.14	2	0.9	2.22
Brain and CNS	2	2.4	0.83	1	2.1	0.48	-	1.2	-	1	0.9	1.11
Hodgkin's Disease	3	1.4	2.14	3	1.2	2.50	2	0.8	3.33	1	0.8	1.67
Non-Hodgkin's Lymphomas	8	3.8	2.11	7	3.6	1.94	5	2.1	2.38	2	1.5	1.33
Leukemia	2	3.6	0.56	2	3.3	0.61	1	1.9	0.53	1	1.4	0.71
Other Sites	16	15.4	1.04	15	14.5	1.03	8	8.1	0.99	7	6.4	1.09

**NOTES:** (1) The four minor civil division area includes Goldsboro and York Haven Boroughs and Fairview and Newberry Townships. Data for Goldsboro and York Haven Boroughs are not presented in the table because the expected numbers for specific cancer sites are too small for meaningful comparisons. The four reported Goldsboro cases include cancers of the colon (1), female breast (1), urinary bladder (1), and other sites (1). The eight reported York Haven cases include cancers of the colon (1), larynx (1), female breast (3), corpus uteri (1), brain and CNS (1), and non-hodgkin's lymphomas (1). The minor civil divisions of residence of two cancer cases could not be determined - buccal cavity and pharynx (1) and colon (1).

(2) Observed numbers of diagnosed cancer cases, Pennsylvania Cancer Registry, Pennsylvania Department of Health. Incorrect residence information on Cancer Registry Report Forms has been corrected.

(3) Expected numbers of cases based on age-sex distribution of the subject populations (1980) and age-sex site specific incidence rates from the Surveillance, Epidemiology, and End Results (SEER) Program, 1978-1981.

**TABLE 10: OBSERVED AND EXPECTED NUMBERS OF DIAGNOSED RADIOGENIC CANCER CASES BY PRIMARY SITE IN A SELECTED FOUR MINOR CIVIL DIVISION AREA<sup>1</sup> WITH SEPARATE DATA FOR FAIRVIEW AND NEWBERRY TOWNSHIPS, JULY 1982 - JUNE 1984**

Primary Site	All Areas <sup>1</sup>			Fairview/Newberry Twp.			Fairview Township			Newberry Township		
	Obs. <sup>2)</sup>	Exp. <sup>3)</sup>	Ratio [Obs./Exp.]	Obs. <sup>2)</sup>	Exp. <sup>3)</sup>	Ratio [Obs./Exp.]	Obs. <sup>2)</sup>	Exp. <sup>3)</sup>	Ratio [Obs./Exp.]	Obs. <sup>2)</sup>	Exp. <sup>3)</sup>	Ratio [Obs./Exp.]
Total	70	64.2	1.09	62	59.9	1.04	38	34.9	1.03	28	25.0	1.04
Esophagus*	-	1.1	-	-	1.0	-	-	0.8	-	-	0.4	-
Stomach	2	3.0	0.67	2	2.8	0.71	1	1.8	0.53	1	1.2	0.83
Colon	18	11.4	1.58	15	10.5	1.43	8	6.1	1.31	7	4.4	1.59
Pancreas	1	3.0	0.33	1	2.7	0.37	1	1.8	0.63	-	1.1	-
Lung	17	18.8	0.90	17	17.7	0.96	8	10.2	0.78	9	7.5	1.20
Breast (Female)	21	16.8	1.27	17	15.8	1.09	11	9.2	1.20	6	8.4	0.84
Thyroid*	1	1.8	0.58	1	1.7	0.59	1	1.0	1.00	-	0.7	-
Non-Hodgkin's Lymphomas	8	3.8	2.11	7	3.6	1.94	5	2.1	2.38	2	1.5	1.33
Multiple Myeloma*	-	1.1	-	-	1.0	-	-	0.6	-	-	0.4	-
Leukemia	2	3.8	0.58	2	3.3	0.61	1	1.9	0.53	1	1.4	0.71

NOTES: (1) The four minor civil division area includes Goldsboro and York Haven Boroughs and Fairview and Newberry Townships. Data for Goldsboro and York Haven Boroughs are not presented in the table because the expected numbers for specific cancer sites are too small for meaningful comparisons. The two reported Goldsboro cases include cancers of the colon (1) and female breast (1). The five reported York Haven cases include cancers of the colon (1), female breast (3) and non-hodgkin's lymphomas (1). The minor civil division of residence of one cancer case (colon) could not be determined.

(2) Observed numbers of diagnosed cancer cases, Pennsylvania Cancer Registry, Pennsylvania Department of Health. Incorrect residence information on Cancer Registry Report Forms has been corrected.

(3) Expected numbers of cases based on age-sex distribution of the subject populations (1980) and age-sex site specific incidence rates from the Surveillance, Epidemiology, and End Results (SEER) Program, 1978-1981. The following sites (\*) were not included in the SEER report for 1978-81, thus, data for the 1973-77 period were used: esophagus, thyroid, and multiple myeloma.

(TABLE 10 DATA ARE DISCUSSED ON PAGES 19, 20 AND 21 OF THE TEXT.)