RADIOEMISSION DENSITY AND LUNG CANCER EPIDEMIOLOGY IN THE PORTLAND METROPOLITAN AREA

by

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Abstract

This study was an investigation into the potential association between the incidence of lung cancer and radioemission density in the Portland-Vancouver metropolitan area. Incidence rates of lung cancer for the period 1963-1977 were calculated based on three geographic classification schemes and compared to radioemission density estimates. Additionally, geographic distance from each of two potential sources of exposure was used as a surrogate measure of radioemission density exposure.

No direct evidence of an association between radioemission density and risk of lung cancer was found in this study. Several significant associations were identified through the analysis; however these associations were not consistent across the classification modalities employed. Thus their significance is suspect; and the model of exposure is unsupported. This lack of support for the association should not be construed as evidence that no association exists, only that such an association was not identified within this dataset. Caution is therefore suggested in the interpretation of these findings due to the inconclusive nature of the results.

Background

Electromagnetic fields (EMFs) have only in recent decades been suspected as an environmental and occupational factor in carcinogenesis. The earliest reports from 1950 to 1975 are predominantly anecdotal, unsupported by clinical or laboratory evidence. But as public exposure to these EMFs has grown through increased use of new technology and equipment, so has the body of evidence suggesting, and even supporting, associations between EMFs and a variety of neoplasms.

The debate was thrust into the public spotlight by a publication in 1979. (Wertheimer and Leeper 1979) In this seminal report, one of the first associations between residential EMF exposure and childhood leukemias was reported. As a result, intense efforts and resources were committed to investigating this potential for carcinogenesis linked to EMFs not just in the workplace, but in the homes of the public. This debate has been marked by confusion, controversial evidence, and criticism.

In spite of this considerable debate, far less attention has been paid to environmental exposures in the radiofrequency range. It has been suggested that the higher frequencies of EMFs, specifically the radio frequency and microwave (RF/MW) bands, may play a role in carcinogenesis. (Cherry 1998) They represent the 50-3500 MHz frequency range, including radio and television broadcasts, two-way radios, cellular phones, and microwave radar systems.

Typically, EMFs in the 50-60 Hz range are studied the most frequently, as this is the range of electric power transmission. But with the ever-increasing demand for wireless communications, concern with regard to the higher RF/MW frequencies is justified. Cellular and molecular research have implicated both the stable emission

density and fluctuating modulation pulses in the linkage, but their role is still unclear. Although it is still not possible to definitively prove a causal connection, numerous experimental investigations and epidemiological studies have reported significant associations with different cancers. But these associations have been difficult to replicate in successive studies. (Cherry 1998, Adey 1990, Savitz 1988)

In the absence of a simple, reliable measure of exposure to EMF, the distance of a dwelling or workplace from a transmission source has been taken as a proxy measure of exposure. Such indirect measures have been criticized because they do not take into consideration variations in field intensity over time, nor the duration of the actual exposure. (Miller 1980, Bonnell 1982) However it remains a crude yet simple assumption that any associated risk would be greatest among individuals who live or work closest to the source of the exposure. Residential proximity to a source can also be established relatively simply for large populations of people, and such a measure is readily understood.

Residential exposure to RF/MWs is detailed in a population-based study of people in three areas surrounded by radiotowers in North Sydney, Australia. (Hocking et al 1996) In this study, an association was found between residential proximity to the transmission towers and increased incidence of childhood lymphatic leukemia. The level of exposure in the residences was considered sufficient to demonstrate a positive association between RF/MW and an increased risk of cancer, based on proximity to the towers.

A second study also detailed the increased risk of leukemia in a population living around a regional television transmission tower near Sutton Coldfield in Great Britain.

(Dolk et al 1997) Initially responding to a reported cluster of leukemias and lymphomas among residents, the researchers were not only able to confirm an excess of leukemias, but also found a decline in risk with distance from the site. They also found "declines in skin melanoma and bladder cancer with distance from the transmitter site." These declines in risk were replicated to a lesser extent in a follow-up study of 20 other high power television and FM radio transmitters in Great Britain by the same authors. (Dolk et al 1997)

In a third study, McDowall investigated lung cancer mortality as a function of proximity to an EMF source. (McDowall 1986) He described a cohort study in East Anglia, UK, of 7631 people who in 1971 had reported living within 30m of an overhead high tension power line, or within 50m of an electrical transformer substation. Using Standardized Mortality Ratios (SMR) he reported a significant excess of lung cancer in women (SMR=175) but not in men (SMR=109). Even when the study was expanded to include cases of leukemia and other lymphomas, only the lung cancer showed an increasing gradient in SMR with proximity to the power source. It was noted that the overall mortality from cancer in this cohort was consistent with expected levels in the region surrounding the study area, as well as in line with national mortality from major lymphatic and hematopoietic tissue neoplasms.

Despite the difficulties involved with exposure measurement, a few such studies have been reported in the literature. Typically these studies involve measurements of occupational exposure and retrospective analysis of cases. Often they are case reports resulting from accidental exposures or high-risk occupations, such as electric company linemen, military career, and foreign embassy personnel. (Szmigielski 1996, Guenel et al

1996, Milham 1985, Pollack 1979) At the highest levels of exposure, typically in workers exposed to high or unknown levels of EMFs, the associations with an elevated risk of cancer seem stronger. This risk to workers is seen as abnormally high rates of neoplasms that are usually present at low or very low incidence levels in the general population. With declining exposure estimates, incidence rates fall within expected rates and the risk of confounding increases due to other environmental or occupational exposures.

One such study was performed among a nested case-control study of electric utility workers in Quebec, Canada and France. (Armstrong et al 1994) After calculation of odds ratios, significant associations with exposure to pulsed electromagnetic fields (PEMFs) were seen with cancers of the lip, buccal cavity, pharynx, stomach, and lung. Even after adjustments for high-risk occupational exposure, the Odds Ratio for lung cancer was 3.11 (95 percent CI 1.60-6.04) in the highest exposure group. As this finding was not a prior hypothesis of the investigators, the results were unexpected. But it does coincide with other reports of associations between EMFs and lung cancer. (Wertheimer and Leeper 1987, McDowall 1986, Milhan 1985, Vagero and Olin 1983) Additionally, no associations were found between PEMFs and cancers previously expected to be associated with magnetic fields (leukemia, other hematopoietic cancers, brain cancer, and melanoma).

All of the above studies have limitations and weaknesses mostly due to study design and inability to control variables of exposure, distance, and diagnostic accuracy. (Cherry 1998, Dolk et al 1997, London et al 1991) Still they share a common thread of findings suggestive of an association between EMFs and carcinogenesis. Their collective

impact is an indication of urgently needed further research in both epidemiology and in cellular and molecular mechanisms. (Adey 1990)

Many studies in the U.S., Europe, and the Scandinavian countries have sought to explain the molecular and biochemical basis for an association between EMFs and carcinogenesis. (Cherry 1998) But intensive retrospective epidemiological studies mixed with lab experiments on cell lines and animals have been so far unable to prove the existence and character of a specific biochemical, molecular, or cellular mechanism for the associations reported. One of several hypotheses under intense scrutiny is melatonin and its involvement in scavenging free radicals at the cellular level. (Stevens 1997)

One possible mechanism for this association involves EMF suppression of melatonin production. (Ronco and Halberg 1996, Stevens and Davis 1996, Reiter 1993, Stevens 1993, Stevens 1987,) As described in his text "The Melatonin Hypothesis", Stevens proposes that exposure to EMFs may disrupt the function of the pineal gland and its primary hormone, melatonin. (Stevens et. al. 1997) The consequence of this disruption is a lowering of melatonin production during the nocturnal sleep cycle. The result of lower melatonin production is a diminution of nocturnal DNA repair with an expected increase in the long-term risk of breast cancer.

Melatonin has been shown in the laboratory to inhibit the growth of cancer cells, transplanted into research animals. (Blask 1997, Reiter 1997, Loscher and Mevissen 1994) It is believed to function as a scavenger of free radicals at the cellular level, contributing in healthy cells to what is termed the "antioxidative defense system" (Reiter et al 1995). The potential result of lowered melatonin production is a reduction in the cell's ability to prevent as well as repair damage resulting from oxidative or carcinogenic

sources, such as smoking and occupational or environmental exposures. (Reiter et al 1995)

Melatonin suppression has been reported in animals (Reiter 1993, Loscher and Mevissen 1994), and in humans (Burch et al 2000, Burch et al 1999, Wilson et al 1990), although there is wide variation in both the exposure conditions and the degree of melatonin suppression. Stevens states "The body of evidence is sufficient to bind electric power over for trial, but not nearly adequate to render a verdict." (Stevens 1994) Given the results reported in the aforementioned studies, it is plausible that associations may yet remain undiscovered, and require further research to bring us closer to such a verdict.

Concurrently with these research efforts, a number of regulatory agencies have investigated the potential for injury to health arising from exposure to EMFs. In the mid-1970's the U.S. Environmental Protection Agency was involved in a project to document population exposure to broadcast radiation. (Tell and Mantiply 1980) As part of a nationwide program of monitoring and assessment of radiofrequency and microwave levels, Portland, Oregon, was one of 15 metropolitan sites surveyed for population exposure levels of non-ionizing radiation. This nationwide effort was the result of the National Environmental Policy Act of 1969, which required agencies of the Federal Government to evaluate the effects of their actions on the quality of the human environment. For the Federal Communications Commission, this meant the development and adoption of exposure standards based on human exposure to radiofrequency energy emitted by FCC-regulated transmitters and facilities. (FCC 96-326 1996) At that time, there were no national standards regarding environmental exposure, only an advisory

standard for occupational exposure issued by the Occupational Safety and Health Administration.

At about the same time, a statewide uterine cancer study raised the issue of association between incidence of endometrial adenocarcinoma and residential proximity to TV broadcast towers. With the availability of the EPA radiowave density estimates for Portland-Vancouver metropolitan area census tracts, and investigation of incidence of several types of cancer by census tract and census tract regions was proposed by William Morton, M.D., Dr.PH, and David Phillips, Ph.D. Funding for the project was awarded in 1978, and the study began.

At the conclusion of the above study, several significant associations had been found between radiowave density levels and the occurrence of several types of cancer. Notably the FM band was correlated with breast cancer and non-lymphatic leukemia, while lymphatic leukemias and uterine adenocarcinoma were correlated to the high VHF band. Further associations between pancreatic and liver cancers were also observed. (Morton and Phillips 1983)

During the collection of cancer data for this larger study, lung cancer incidence data for the 15-year period from 1963 to 1978 were collected and stored, but never analyzed. Because of the availability of this lung cancer data, and a relative lack of published literature regarding lung cancer association with non-ionizing radiation, the current thesis project was undertaken.

This project represents the unique opportunity to combine a series of events into a study of lung cancer, the perspective of which is poorly represented in the literature. It is anticipated that in addition to furthering the investigation into a hypothesized linkage

between incidence of lung cancer and exposure to radioemission densities, the study will provide additional baseline information that can serve as the basis for ongoing investigations of lung cancer in the Portland-Vancouver Metropolitan area. It is also an opportunity to compare the results to previous studies of the incidence of other cancers in relation to radioemission densities. Lastly, it may serve as a blueprint for subsequent studies in the Portland-Vancouver Metropolitan area as well as other urban areas exposed to radioemissions.

Methodology

Subject Selection and Data Collection

Drs. Morton and Phillips developed the dataset used for this analysis through the funding of a larger study in 1978. (Morton and Phillips 1983) This previous study explored a proposed relationship between EPA-measured radiowave density levels and the incidence or mortality rates of several types of cancer in the Portland-Vancouver metropolitan area. These cancers included leukemia, uterine adenocarcinoma, breast cancer, and pancreatic, gallbladder and liver cancers. Although lung cancer data were intended to be analyzed along with the preceding cancer data, insufficient funding precluded analysis until now.

The data collection process began in 1978 and, for lung cancer records, covered all cases diagnosed in the years 1963 to 1977. Cases of lung cancer were drawn from the patient records at 24 hospitals in the four counties of the Portland-Vancouver metropolitan area. At each hospital, several sources were utilized to compile lists of cases, including tumor registries, discharge diagnosis indices, and tissue pathology report files. The case-finding method was identical to that used by the Surveillance, Epidemiology, and End Results (SEER) program of the National Cancer Institute. (Morton and Phillips 1983)

Once cases were identified, their hospital charts were pulled and abstracted according to a protocol published previously. (Morton et al 1979) Histologic diagnoses were accepted as listed in the patient charts. A list of diagnosis categories can be found in table 11 in the appendix. Abstract forms from each location were collected and compiled alphabetically into a central file, with duplicate reports merged into single

records. This case file was checked against an alphabetic list of lung cancer death certificates for the years 1963-1977. An additional 10% (708) of cases were identified through this process which were not recorded in the initial hospital search. These additional cases were located in hospital records, abstracted, and combined with the central case file.

The information on the abstract forms was coded numerically, using 1970 census tract numbers and boundaries. After cross-checking and verification of the data, it was stored on IBM punch cards. These punch cards were read in January 1997, and imported into Excel 97 (Microsoft 1997) and SPSS (SPSS Inc. 1997) for verification of data accuracy. Each variable was checked for completeness and out-of-range values indicating possible errors during the data transcription. Potential errors were identified, and referred back to the original abstract forms for verification and correction.

Cases of lung cancer were sorted into eight histologic groupings according to the recorded diagnosis. These diagnoses were made according to the 1967 Kreyberg system of histologic classification. (Kreyberg et al 1967) These eight groups and the included diagnostic categories are found in table 12 in the appendix. It is important to note that these histogroups are not exclusive. In fact, lung cancers tend to show not only grades of differentiation within a single cell type, but also mixtures of cell types. In one study by Roggli et al. of 100 cases, only 34% of tumors were found to be homogeneous in their major classification groups. Forty-five percent of these cases were considered a mixture of the major classification groups by cell type. (Roggli et al 1985) Due to this heterogeneous nature of lung cancers, some cases are included in two or more

histogroups. However this analysis was designed to evaluate each histologic group independently, so multiple representation of cases in the analysis was not an issue.

Radiowave Density Measurement

Estimation of radio frequency exposure for the study population was based on a process described by Tell and Mantiply (Tell and Mantiply 1980). During the period July 25 to August 5, 1977, measurements of the radiofrequency field strengths of all the VHF and FM domestic broadcast stations in the Portland metropolitan area were made with an automated measurement system of calibrated antennas, a spectrum analyzer, and a minicomputer data acquisition system.

Using this system, electric field strengths were measured at 38 locations throughout the Portland and Vancouver area. In total, 810 field strength values were recorded for 12 FM radio stations (88-108 MHz), 2 low VHF television stations (54-88 MHz), and 3 high VHF television stations (176-216 MHz). These are the three broadcast frequency ranges used for this investigation. Measurements of the 108-176 MHz band, predominantly used by two-way radio systems in the metropolitan area, were not made due to the longer time periods required to record representative values for this frequency band. Also not available were measurements of the AM bands (0.535-1.605 MHz), which were made by the EPA but not made available to the researchers. (Morton 1983)

The broadcast locations, frequencies, and power for the VHF television and FM radio bands are listed in the appendix in table 13 and shown on map 1. All five of the VHF television stations are broadcast from three towers located in the hills immediately west of downtown Portland. These towers are identified as N1, N2, and N3. The 13 FM

radio stations are broadcast from four locations around Portland; two from the hills west of downtown Portland, eight from the southwest near Council Crest, two more from the east at Mt. Scott, and one from the Reed College campus in southeast Portland. The southwest site with the eight FM stations is identified as S1. Because of the broadcast power of 0.01 kW, the Reed College site has been excluded from this analysis.

The EPA Office of Radiation Programs developed a computer algorithm to estimate VHF broadcast exposure for 1194 census blocks groups within the central part of the metropolitan area, based on the measured field strength values. As part of the algorithm, the population of each block group and the geographical coordinates for each block group centroid were used to develop a field strength propagation model for each of the broadcast stations. These models were then used to calculate expected field strengths and exposures for each of the block groups. These exposures were expressed in terms of the equivalent power density of all broadcast signals within each of the three VHF bands. The exposure values for each block group were then used to create population-weighted census tract exposures. From these 1194 block groups, estimated exposures were available for 204 of the 265 census tracts in the Portland-Vancouver metropolitan area, concentrated within the center of the metropolitan area. An abbreviated map of census tracts in the metropolitan area can be found in the appendix as map 2.

Table 14 lists the mean radiowave density values for the geographic regions of grouped census tracts. In comparing the FM to the VHF broadcasts, it can be seen that the FM band broadcast density is generally one order of magnitude greater than either of the VHF bands. It is plausible that if this greater density level is the determining factor

(as opposed to some other characteristic of the exposure), then lung cancer incidence would be most apt to be associated with the FM band.

Analysis

Case Description and Correlation to Potential Confounders

To investigate the pattern of risk by histologic type, the percentage distribution by histologic types of lung cancer split by gender was calculated. This distribution pattern was then compared to published studies of lung cancer for the comparable time period.

Potential confounding of the analysis was investigated through observation of the distribution of variables contained in the dataset generally considered associated with lung cancer. Although other occupational, environmental, and genetic factors are well documented in the literature (Samet 1994), only those variables contained within the dataset were available for inclusion in the analysis. The most prominent of these available variables was smoking, available only for the cases but not for the population at risk. Other potential confounders identified for investigation included asthma, tuberculosis, and chronic obstructive pulmonary disease. For each, percentage distributions were calculated and compared to reported rates of the same variable in the lung cancer literature.

Calculation of Standardized Incidence Ratios

As this study was a risk estimation for the entire Portland-Vancouver metropolitan area, the principle estimate of risk of lung cancer was the population-based rate per 100,000. To accomplish this, the total cases within each histologic group over the 15-year study period were summed, then converted to a mean annual rate. Age- and sex-adjustment was made of these by the direct method, using the total 1970 Portland-Vancouver metropolitan population as the standard. This age- and sex-adjusted rate was

then used to calculate the expected case rate per unit of analysis (i.e. census tract, geographic region, and distance zone).

The observed and expected rates were then combined to compute the Standardized Incidence Ratio, or SIR, according to the following formula:

$$SIR = [\ (Total\ observed\ cases)/(Total\ expected\ cases)\ ] * 100$$

This SIR is the estimate of risk used for this investigation. Throughout the study, all the manipulations and calculations were made using either Microsoft's Excel 97 or SPSS Inc.'s SPSS 8.0.

Regression to Radiofrequencies

For the first series of regressions, the independent variable was the radioemission density. This series of regressions was undertaken at three levels of geographic exposure – individual census tracts, geographic regions, and concentric distance zones around each of the to broadcast towers included in this study.

For the individual census tracts, exposure values were based on the population-weighted density values calculated from the EPA block group data. These census tract exposure values were then population-weighted to generate exposure values for the geographic regions and distance zones respectively.

Of the total 265 census tracts in the study area, exposure values were only available for 204 tracts. Subsequently, exposure values could be calculated for only 21 of the 27 geographic regions. And for the distance zones, 8 of the 9 zones had useable exposure values. For the units of analysis where no radioemission density estimates were

provided, their cancer data were excluded from the radiofrequency band density regressions.

Regression to Distance From Towers

Two of the broadcast tower sites were selected as reference points for the distance measurements. The N2 tower was selected as the first site, due to its geographic location roughly midway between the N1 and N3 towers west of downtown Portland. The second site was the S1 tower in southwest Portland near Council Crest. A map of these sites can be found in the appendix.

Distances from the broadcast tower sites were measured from two perspectives. The first was the actual distance between the indicated broadcast tower and the population centroid of the individual census tracts.

The second perspective was achieved by grouping into sub-regions, or concentric zones, all census tracts with their population centroids falling within successive 4 km radius bands surrounding each broadcast site. The result of this grouping was nine concentric distance zones, defined by their radial distance from the tower of interest. This system of grouping was derived from a series of publications using a similar process to investigate environmental risks around putative sources (Hocking et. al. 1996, Stone 1988, Bithell and Stone 1989, Elliott et al 1992, Shaddick and Elliott 1996). A list of census tracts by zone for each tower can be found in tables 16 & 17 in the appendix.

Results

Case Description and Relation to Confounders

For the 15-year period, 7087 cases of lung cancer were identified. Of these, 5485 cases (77.4%) were among men and 1602 cases (22.6%) were among women. In 6387 cases (90.1%) a specific histologic diagnosis could be made. Among men and women, specific diagnoses were available for 4495 (90.1%) and 1442 (90.0%) cases, respectively. For the remaining 700 cases (9.9%), no tissue diagnosis was available.

Table 1 is a distribution of cases by histologic diagnosis group. For males, squamous cell carcinoma represented the greatest proportion of cases (2105 cases, 38.4% of total cases). This was almost twice the proportion of the next highest histologic group among males, the adenocarcinoma (including clear cell and alveolar cell types) group, with 1145 cases, or 20.9% of total cases. Following this were the undifferentiated small cell, undifferentiated unspecified cell, and undifferentiated large cell groups, with 14.2, 12.6, and 9.1 percents, respectively. Lastly were the mesothelioma and sarcoma groups with 1.7 and 0.3 percents. Again, it is important to note that the histologic group proportions are not cumulative, as some case diagnoses are included in more than one histologic group.

For females, the adenocarcinoma group contained the highest number of cases with 467 (29.2 %). Next came squamous (20.9%), undiff. small cell (16.1%), undiff. cell (14.2%), undiff. large cell (10.9%), mesothelioma (2.0%), and sarcoma (1.1%).

This disparity in histologic cell type distribution between men and women is consistent with other published studies showing squamous cell carcinoma to be the

predominant cell type among men, while adenocarcinoma is predominant for women. (Wu-Williams and Samet 1994, Vincent et al 1974)

Table 1: Distribution of lung cancer cases among males and females, by histologic group

Histologic grouping	Males		Females		Total	
	No.	%	No.	%	No.	%
Squamous	2105	38.4	335	20.9	2440	34.4
Adenocarcinoma	1145	20.9	467	29.2	1612	22.7
Undif. Large cell	500	9.1	174	10.9	674	9.5
Undif. Small cell	777	14.2	258	16.1	1035	14.6
Undif. Cell	690	12.6	228	14.2	918	13.0
Sarcoma	19	0.3	17	1.1	36	0.5
Mesothelioma	91	1.7	32	2.0	123	1.7
Total	5485	-	1602	-	7087	-

Note: Histologic groupings are not exclusive; some cases appear in more than one group. Percentages are the proportion to total cases, including "unknown and clinical diagnosis only" cases in the total.

Although the percentage of adenocarcinomas is lower in this study than the estimated 35% in the Vincent study, it is possible that smokers represented a larger portion of the cases in this study. Because adenocarcinomas are the most predominant histologic cell group among non-smokers, this could account for the variation seen here, where the percentage of smokers is quite high.

As anticipated, cases with a history of smoking are highly represented in the study sample. Smokers comprise 93.5% of the total overall cases of lung cancer with known smoking status. For males, smokers represent over 96% of all cases in six of the eight histogroups, and as high as 98.9% for undifferentiated large cell. In addition, even considering gender-based discrepancies, there are more female smokers than commonly

reported in the literature. Within particular histogroups, the percentage of smokers is higher than reported in many other epidemiological studies of the same time period. Table 2 lists the relative proportions of known smokers within the database.

Table 2: Proportion of male and female lung cancer cases who ever smoked, by histologic type

Histologic grouping	Males			Females		
	Total cases	Known status	Known Smokers (%)	Total cases	Known status	Known Smokers (%)
Squamous	2105	1854	1804 (97.3)	335	292	269 (92.1)
Adenocarcinoma	1145	971	933 (96.1)	467	391	265 (67.8)
Undif. Large cell	500	449	444 (98.9)	174	152	142 (93.4)
Undif. Small cell	777	680	671 (98.7)	258	230	208 (90.4)
Undif. Cell	690	563	555 (98.6)	228	172	144 (83.7)
Sarcoma	19	15	11 (73.3)	17	11	3 (27.3)
Mesothelioma	91	74	57 (77.0)	32	21	11 (52.4)
Total	5485	4642	4503 (97.0)	1602	1309	1062 (81.1)

Note: "Known Status" includes only cases where smoking status was stated. Cases with unknown or blank fields were excluded.
"Known Smokers" includes current and former users of cigarettes, cigars, and pipes.

The confounding effects of other variables were investigated. The proportions of cases with a history of asthma, tuberculosis, and chronic obstructive pulmonary disease (COPD) were calculated. But unlike smoking, the extent of their representation within the dataset was roughly equal to that seen in other studies of lung cancer. (Samet 1994, Tockman 1994) An example of this comparison for tuberculosis can be seen in Table 3. It was thus presumed that the role of these confounders was no different than in other reported studies, so no attempt was made to adjust for them.

Table 3: **Relative Frequencies (%) of Lung Cancer Cases Reporting a History of Tuberculosis**

Study	Gender	Percentage of cases	Percentage of controls
Zheng et al (in Samet 1994)	Males	26	20
	Females	12	8
Current study	Males	27.5	Unknown
	Females	14.7	Unknown

Socioeconomic status has also been viewed as a potential confounder in studies of lung cancer. A previous investigation into the association between SES and lung cancer was performed on this same dataset, whereby an inverse correlation was found in three histologic groups between lung cancer incidence and SES in males, but not in females. (Bryan 1999) To test the potential interaction with radioemission density, multiple regressions were run for the same three histologic groups reported to be associated with SES. However, the results of these regressions were not affected by the addition of the SES variable. It was thus determined that the SES score contained in this dataset did not appear to be a confounder, and was subsequently not controlled for in the remaining analyses.

Radiowave Band Density Regression

Census Tract

Simple linear regression analysis was performed with each of the individual radiowave band densities as the predictor variable, and the natural log of the SIR in the individual census tract as the dependent variable. Initially a histogram plot of the residuals suggested a positive skew, so a natural log transformation of the SIR was done to improve the linear fit of the model. This transformation led to a roughly normal distribution for each set of SIRs.

Most of the individual census tract correlations with the FM band were negative. That is, five of the six significant lung cancer SIR associations found were inversely correlated with radiowave density. (Table 3) In males these negative correlations were with SIRs of total cancer (p=.025), squamous (p=.002), small cell (p=.000), and undifferentiated unspecified cell (p=.007). For females, the only significant SIR association was with the squamous histogroup (p=.002). The exception was the one positive association with sarcoma in males (p=.000).

For the High VHF band, the only significant association was with squamous cell carcinoma in males (p=.004). This too was inversely correlated with radiowave density. (Table 4) No significant associations were found in females.

Both of the significant associations with the Low VHF band were inversely correlated with radiowave density. (Table 5) For males the association was found in the squamous cell histogroup (p=.000), while in females the association was with total cancers (p=.000).

Table 4: Correlation of FM Band Density to SIR in Census Tracts

	Gender	r	R2	SE	Beta	SE	p
Total	Males	-0.152	0.023	0.559	-0.001	0.000	.025*
	Females	0.010	0.000	0.940	0.000	0.000	0.878
Squamous	Males	-0.205	0.042	0.038	-0.001	0.000	.002**
	Females	-0.205	0.042	0.851	-0.001	0.000	.002**
Adeno	Males	-0.045	0.002	1.123	-0.001	0.001	0.509
	Females	-0.071	0.005	2.060	-0.001	0.001	0.296
Large Cell	Males	-0.053	0.003	1.882	-0.001	0.001	0.433
	Females	-0.081	0.007	2.605	-0.001	0.001	0.231
Small Cell	Males	-0.256	0.066	1.453	-0.002	0.001	.000**
	Females	-0.132	0.017	2.462	-0.002	0.001	0.052
Undif. Cell	Males	-0.018	0.033	1.563	-0.002	0.001	.007**
	Females	0.043	0.002	2.565	0.001	0.001	0.522
Sarcoma	Males	0.255	0.065	1.778	0.003	0.001	.000**
	Females	-0.031	0.001	1.776	0.000	0.001	0.645
Mesoth	Males	-0.046	0.002	2.723	0.000	0.001	0.494
	Females	-0.072	0.005	2.184	-0.001	0.001	0.289

Table 5: Correlation of High VHF Band Density to SIR in Census Tracts

		r	R2	SE	Beta	SE	p
Total	Males	-0.046	0.002	0.566	-0.002	0.003	0.502
	Females	-0.081	0.007	0.937	-0.007	0.006	0.234
Squamous	Males	-0.191	0.037	0.853	-0.015	0.005	.004**
	Females	-0.056	0.003	2.281	-0.012	0.014	0.406
Adeno	Males	0.024	0.001	1.124	0.002	0.007	0.725
	Females	-0.005	0.002	2.063	-0.009	0.013	0.464
Large Cell	Males	-0.011	0.000	1.884	-0.002	0.012	0.869
	Females	-0.057	0.003	2.609	-0.014	0.016	0.400
Small Cell	Males	-0.110	0.012	1.494	-0.015	0.009	0.106
	Females	0.004	0.000	2.484	0.000	0.015	0.953
Undif. Cell	Males	-0.043	0.002	1.587	-0.006	0.010	0.523
	Females	-0.020	0.000	2.567	-0.004	0.016	0.767
Sarcoma	Males	0.000	0.000	1.839	0.000	0.011	0.995
	Females	0.100	0.010	1.768	0.016	0.011	0.139
Mesoth	Males	-0.077	0.006	0.001	-0.019	0.017	0.255
	Females	-0.091	0.008	2.180	-0.018	0.013	0.179

N= 219 for all groups; r= correlation coefficient

**=p<0.05 **=p<0.01*

Table 6: Correlation of Low VHF Band Density to SIR in Census Tracts

		r	R2	SE	Beta	SE	p
Total	Males	-0.06	0.004	0.565	-0.009	0.011	0.376
	Females	-0.248	0.062	0.911	-0.064	0.017	.000**
Squamous	Males	-0.355	0.126	0.812	-0.085	0.015	.000**
	Females	-0.061	0.004	2.281	-0.038	0.043	0.369
Adeno	Males	0.006	0.000	1.124	0.002	0.021	0.932
	Females	-0.117	0.014	2.051	-0.066	0.038	0.084
Large Cell	Males	0.028	0.001	1.884	0.014	0.035	0.681
	Females	-0.079	0.006	2.606	-0.057	0.049	0.244
Small Cell	Males	-0.052	0.003	1.501	-0.021	0.028	0.446
	Females	-0.097	0.009	2.472	-0.066	0.046	0.152
Undif. Cell	Males	-0.015	0.000	1.589	-0.006	0.030	0.827
	Females	-0.089	0.008	2.557	-0.063	0.048	0.191
Sarcoma	Males	-0.010	0.000	1.839	-0.005	0.034	0.883
	Females	0.049	0.002	1.775	0.024	0.033	0.474
Mesoth	Males	-0.085	0.007	2.716	-0.064	0.051	0.211
	Females	-0.084	0.007	2.183	-0.051	0.041	0.215

N= 219 for all groups; r= correlation coefficient
**=p<0.05 **=p<0.01*

Geographic Region

For the regression analysis of census tracts grouped by Geographic Region, it was determined that the natural log transformation used for the individual census tract analysis was not necessary. Initial histogram plots of the distribution of residuals indicated that the SIRs were already normally distributed, so no transformation of the geographic region SIRs was made. A complete list of SIRs by histologic group and gender can be found in Tables 7 and 8.

For the FM band, there were two significant associations found. (Table 9) Both associations were found in males, inversely with the total cancer group (p=.042) but directly with the sarcoma histogroup (p=.007). There were no significant associations with the FM band for females.

For the High VHF band, four of the six significant associations found were positively correlated to radiowave density. (Table 10) Among females these associations were with the total cancer (p=.008), squamous cell (p=.006), and sarcoma (p=.000) histogroups. In males there was a positive association with mesothelioma (p=.001). The remaining negative correlations were found with adenocarcinoma in males (p=.001), and mesothelioma in females (p=.037).

As for the Low VHF band, four of the six associations seen with High VHF band density were also observed. (Table 11) Positive correlations were found with female cases of squamous cell (p=.033) and sarcoma (p=.018). The negative correlations were found with adenocarcinoma in males (p=.014) and mesothelioma in females (p=.026).

Table 7: **SIRs by Geographic Region for Males**

Geographic. Region	Total Cancer	Squam	Adeno	Undif Large	Undif Small	Undif Cell	Sarc	Mesoth
Multnomah Co.								
Northwest	102	144	31	139	69	52	0	630
West Hills	58	38	73	86	61	69	445	46
Southwest	75	79	61	73	99	64	0	76
Downtown	160	170	152	130	181	115	0	37
Peninsula	112	115	114	114	106	114	92	166
North Central	131	132	117	146	106	147	0	163
Central	124	150	113	102	113	134	154	61
South Central	103	95	98	102	107	148	158	127
Southeast	95	104	88	86	93	87	148	74
East Southeast	113	127	111	96	110	110	0	59
Northeast	88	85	104	70	92	82	0	48
East Northeast	83	80	106	48	68	98	188	60
East	111	129	93	97	75	85	162	143
Clackamas Co.								
Northwest	84	80	97	79	82	50	178	120
North Central	96	89	92	76	95	91	176	170
Central	83	86	88	41	78	95	0	54
East	99	103	83	52	111	132	455	0
Southwest	87	113	70	99	74	64	0	144
Washington Co.								
Northeast	92	85	101	111	87	111	88	104
Southeast	91	74	90	171	105	98	0	118
Central	82	70	83	62	97	101	0	59
Northwest	76	75	103	132	84	133	0	0
Clark Co.								
West Vancouver	89	74	98	121	82	104	0	174
East Vancouver	97	86	100	152	137	62	0	195
Northeast Suburb	86	70	116	154	78	54	309	0
Southeast	107	93	98	136	138	64	259	220
North	96	79	98	168	92	100	0	70

Table 8: **SIRs by Geographic Region for Females**

Geographic. Region	Total Cancer	Squam	Adeno	Undif Large	Undif Small	Undif Cell	Sarc	Mesoth
Multnomah Co.								
Northwest	188	197	147	247	176	0	1528	0
West Hills	104	124	122	108	59	99	0	0
Southwest	73	99	43	93	116	29	0	0
Downtown	137	112	144	42	152	203	0	62
Peninsula	101	108	82	76	115	182	0	52
North Central	111	120	76	111	128	93	0	273
Central	85	98	70	49	63	167	148	76
South Central	119	146	126	138	97	129	162	126
Southeast	78	65	98	56	107	37	0	70
East Southeast	105	121	108	139	109	84	207	115
Northeast	90	114	83	93	87	116	154	77
East Northeast	115	121	110	129	97	93	110	177
East	130	110	131	82	114	144	0	120
Clackamas Co.								
Northwest	85	79	100	74	39	73	215	0
North Central	86	96	68	48	111	96	0	54
Central	114	131	130	95	107	73	321	0
East	116	77	79	147	202	69	0	0
Southwest	99	155	147	150	40	0	324	0
Washington Co.								
Northeast	86	46	87	76	100	83	214	0
Southeast	89	66	113	107	86	33	234	125
Central	78	43	86	83	89	101	0	0
Northwest	62	48	36	94	63	145	0	0
Clark Co.								
West Vancouver	99	91	106	133	59	117	215	224
East Vancouver	103	95	86	160	78	53	239	256
Northeast Suburb	120	96	148	252	100	84	0	429
Southeast	111	63	126	151	145	117	0	179
North	109	109	141	124	71	113	0	373

Table 9: Correlation of FM Band Density to SIR in Geographic Regions

		r	R2	SE	Beta	SE	p
Total	Males	-0.447	0.200	19.693	-0.091	0.042	.042*
	Females	-0.062	0.004	25.944	-0.015	0.055	0.788
Squamous	Males	-0.420	0.177	29.858	-0.128	0.064	0.058
	Females	0.156	0.024	32.716	0.048	0.070	0.499
Adeno	Males	-0.287	0.083	23.050	-0.064	0.049	0.207
	Females	0.056	0.003	29.104	0.015	0.062	0.808
Large Cell	Males	-0.218	0.048	32.665	-0.068	0.069	0.342
	Females	-0.079	0.006	58.435	-0.043	0.124	0.733
Small Cell	Males	-0.287	0.082	27.146	-0.075	0.058	0.207
	Females	-0.282	0.079	32.195	-0.088	0.068	0.216
Undif. Cell	Males	-0.174	0.030	30.152	-0.049	0.064	0.450
	Females	-0.013	0.000	52.609	-0.006	0.122	0.957
Sarcoma	Males	0.574	0.329	104.11	0.676	0.221	.007**
	Females	-0.118	0.014	334.33	-0.367	0.711	0.611
Mesoth	Males	-0.169	0.029	129.68	-0.206	0.276	0.464
	Females	-0.326	0.106	107.42	-0.343	0.228	0.150

Table 10: Correlation of High VHF Band Density to SIR in Geographic Regions

		r	R2	SE	Beta	SE	p
Total	Males	-0.119	0.014	21.856	-0.334	0.64	0.608
	Females	0.565	0.319	21.45	1.875	0.628	.008**
Squamous	Males	0.143	0.021	32.565	0.602	0.954	0.535
	Females	0.575	0.330	27.103	2.431	0.794	.006**
Adeno	Males	-0.652	0.425	18.243	-2.004	0.534	.001**
	Females	0.233	0.054	28.351	0.866	0.830	0.310
Large Cell	Males	0.113	0.013	33.256	0.483	0.974	0.625
	Females	0.339	0.115	55.158	2.534	1.616	0.133
Small Cell	Males	-0.312	0.097	26.925	-1.129	0.789	0.169
	Females	0.372	0.139	31.139	1.596	0.912	0.096
Undif. Cell	Males	-0.233	0.054	29.778	-0.911	0.872	0.309
	Females	-0.354	0.126	49.199	-2.380	1.441	0.115
Sarcoma	Males	-0.024	0.001	127.06	-0.392	3.722	0.917
	Females	0.784	0.615	208.99	33.702	6.122	.000**
Mesoth	Males	0.678	0.459	96.736	11.388	2.834	.001**
	Females	-0.457	0.209	101.07	-6.626	2.960	.037*

N= 21 for all groups; r= correlation coefficient
**=p<0.05 **=p<0.01*

Table 11: Correlation of Low VHF Band Density to SIR in Geographic Regions

		r	R2	SE	Beta	SE	p
Total	Males	-0.198	0.039	21.575	-1.795	2.035	0.389
	Females	0.408	0.167	23.731	4.361	2.238	0.066
Squamous	Males	-0.015	0.000	32.901	-0.208	3.103	0.947
	Females	0.466	0.217	29.308	6.343	2.764	.033*
Adeno	Males	-0.526	0.277	20.467	-5.204	1.930	.014*
	Females	0.210	0.044	28.503	2.511	2.688	0.362
Large Cell	Males	0.026	0.001	33.459	0.360	3.156	0.910
	Females	0.179	0.032	57.673	4.315	5.440	0.437
Small Cell	Males	-0.273	0.075	27.259	-3.186	2.571	0.231
	Females	0.202	0.041	32.863	2.782	3.100	0.381
Undif. Cell	Males	-0.197	0.039	30.021	-2.478	2.832	0.392
	Females	-0.205	0.042	51.501	-4.425	4.857	0.374
Sarcoma	Males	0.184	0.034	124.92	9.637	11.782	0.424
	Females	0.509	0.259	289.75	70.481	27.329	.018*
Mesoth	Males	0.401	0.161	120.55	21.675	11.370	0.072
	Females	-0.484	0.234	99.41	-22.61	9.376	.026*

N= 21 for all groups; r= correlation coefficient
**=p<0.05 **=p<0.01*

Concentric zones around N2 and S1 towers

As with the Geographic Region analysis, no transformation of the SIR was necessary for the regression analysis of radiowave density onto the SIR as calculated within the concentric distance zones for the N2 and S1 towers. The predictor variable in each regression analysis was the radiowave density as estimated in the zones surrounding the broadcast tower, while the dependent variable was the SIR calculated for each zone. The complete list of SIRs by histologic group for the zones surrounding each tower can be found in Tables 12 - 15.

Based on the FM band density surrounding the N2 tower, the one significant association found was a positive correlation to small cell carcinoma in males (p=0.002). There were no association found in females. (Table 16) There were no significant associations found with the FM band for any of the zones surrounding the S1 tower, either males or females. (Table 17)

For the High VHF band density around the N2 tower, there were four significant associations found. (Table 18) Two of these were positive correlations to small cell in males (p=.041), and undifferentiated unspecified cell carcinoma in females (p=.038) Negative correlations were found to adenocarcinoma in females (p=.032) and sarcoma in males (p=.024). Again, there were no significant associations found surrounding the S1 tower. (Table 19)

There were five significant associations found between the Low VHF radioemission band and the N2 tower. (Table 20) Four of these were inverse associations. In males, the negative correlations were to the sarcoma (p=.007) and

mesothelioma (p=.030), while for females the correlations were to cases of squamous cell (p=.028) and adenocarcinoma (p=.019). The one direct association was with cases of undifferentiated unspecified cell carcinoma in females (p=.028).

And finally, for the S1 tower, only one significant association was found between the Low VHF broadcast band density and males with small cell carcinoma (p=.035). (Table 21) No other significant associations were found surrounding the S1 tower.

Table 12: **SIRs by Zone around N2 Tower in Males**

N2 Zone	Total Cancer	Squam	Adeno	Undif. Large	Undif. Small	Unspec. Cell	Sarcoma	Mesoth
1	90	87	109	84	102	111	0	35
2	115	119	108	117	115	104	100	97
3	98	99	95	90	101	109	93	103
4	100	95	109	100	94	109	102	112
5	89	87	100	91	97	78	85	112
6	96	99	101	111	97	70	81	55
7	97	100	78	129	93	64	140	119
8	84	85	72	68	90	101	126	105
9	95	102	82	99	84	113	190	99

Table 13: **SIRs by Zone around N2 Tower in Females**

N2 Zone	Total Cancer	Squam	Adeno	Undif. Large	Undif. Small	Undif. Cell	Sarcoma	Mesoth
1	98	53	64	67	81	183	0	0
2	106	108	96	88	112	120	112	59
3	91	93	104	73	105	90	90	93
4	98	109	90	112	81	99	165	131
5	103	93	107	138	105	81	51	168
6	111	114	89	128	142	107	0	59
7	115	125	108	91	74	154	0	0
8	91	86	119	76	82	46	320	169
9	109	90	140	159	92	57	0	146

Table 14: **SIRs by Zone around S1 Tower in Males**

S1 Zone	Total Cancer	Squam	Adeno	Undif. Large	Undif. Small	Unspec. Cell	Sarcoma	Mesoth
1	104	103	93	104	115	95	139	84
2	109	113	101	100	111	117	124	88
3	97	91	105	94	89	96	39	114
4	105	107	114	93	110	101	131	95
5	91	93	94	117	91	74	109	83
6	97	93	99	102	104	87	87	170
7	89	73	100	115	95	72	0	91
8	76	72	72	94	75	102	302	128
9	96	105	76	99	89	115	159	83

Table 15: **SIRs by Zone around S1 Tower in Females**

S1 Zone	Total Cancer	Squam	Adeno	Undif. Large	Undif. Small	Undif. Cell	Sarcoma	Mesoth
1	104	130	108	63	84	101	77	0
2	100	97	99	96	105	112	62	107
3	95	106	90	76	96	100	169	67
4	96	73	95	118	112	99	106	116
5	115	125	121	168	106	69	62	237
6	98	73	95	53	116	139	0	60
7	107	103	95	215	85	97	391	106
8	80	80	115	0	26	88	0	0
9	104	89	125	141	96	62	0	173

Table 16: Correlation of FM Band Density to SIR in N2 Zones

		r	R2	SE	Beta	SE	p
Total	Males	0.562	0.316	7.803	0.171	0.095	0.115
	Females	-0.09	0.008	9.128	-0.027	0.111	0.817
Squamous	Males	0.416	0.173	10.128	0.149	0.124	0.266
	Females	-0.32	0.103	21.138	-0.231	0.258	0.401
Adeno	Males	0.663	0.44	11.437	0.327	0.14	0.052
	Females	-0.578	0.334	18.392	-0.421	0.224	0.103
Large Cell	Males	0.0978	0.009	19.377	0.061	0.237	0.804
	Females	-0.426	0.182	31.178	-0.474	0.381	0.253
Small Cell	Males	0.876	0.767	4.398	0.257	0.054	0.002**
	Females	0.085	0.007	22.841	0.063	0.279	0.827
Undif. Cell	Males	0.339	0.115	19.285	0.225	0.235	0.372
	Females	0.541	0.293	39.271	0.816	0.479	0.132
Sarcoma	Males	-0.571	0.325	44.883	-1.007	0.548	0.109
	Females	-0.086	0.007	114.3	-0.319	1.395	0.826
Mesoth	Males	-0.388	0.151	28.217	-0.384	0.344	0.302
	Females	-0.432	0.187	64.034	-0.992	0.782	0.245

Table 17: Correlation of FM Band Density to SIR in S1 Zones

		r	R2	SE	Beta	SE	p
Total	Males	0.374	0.14	9.86	0.048	0.045	0.321
	Females	0.138	0.019	10.336	0.017	0.047	0.723
Squamous	Males	0.292	0.085	14.812	0.054	0.068	0.445
	Females	0.589	0.347	18.163	0.161	0.083	0.095
Adeno	Males	0.019	0	14.39	0.003	0.066	0.961
	Females	0.04	0.002	13.86	0.007	0.064	0.919
Large Cell	Males	0.055	0.003	9.403	0.006	0.043	0.889
	Females	-0.237	0.056	67.528	-0.199	0.31	0.54
Small Cell	Males	0.559	0.312	11.623	0.095	0.053	0.118
	Females	-0.057	0.003	28.799	-0.019	0.132	0.884
Undif. Cell	Males	0.038	0.001	17.164	0.008	0.079	0.922
	Females	0.113	0.013	24.064	0.033	0.11	0.772
Sarcoma	Males	0.058	0.003	90.473	0.064	0.415	0.882
	Females	-0.055	0.003	132.27	-0.089	0.606	0.885
Mesoth	Males	-0.28	0.078	30.096	-0.106	0.138	0.465
	Females	-0.469	0.22	72.286	-0.465	0.331	0.203

N= 9 for all groups; r= correlation coefficient

**=p<0.05 **=p<0.01*

Table 18: Correlation of High VHF Band Density to SIR in N2 Zones

		r	R2	SE	Beta	SE	p
Total	Males	0.268	0.072	9.091	0.295	0.402	0.486
	Females	-0.187	0.035	9.003	-0.2	0.398	0.63
Squamous	Males	0.125	0.016	11.048	0.163	0.488	0.748
	Females	-0.595	0.354	17.936	-1.551	0.792	0.091
Adeno	Males	0.604	0.365	12.181	1.078	0.538	0.085
	Females	-0.712	0.506	15.836	-1.875	0.699	0.032*
Large Cell	Males	-0.083	0.07	19.403	-0.188	0.857	0.833
	Females	-0.536	0.287	29.098	-2.159	1.285	0.137
Small Cell	Males	0.686	0.471	6.621	0.73	0.292	0.041*
	Females	-0.089	0.008	22.835	-0.237	1.009	0.821
Undif. Cell	Males	0.402	0.161	18.775	0.962	0.829	0.284
	Females	0.695	0.483	33.583	3.792	1.483	0.038*
Sarcoma	Males	-0.737	0.543	36.948	-4.706	1.632	0.024*
	Females	-0.183	0.034	112.78	-2.459	4.982	0.637
Mesoth	Males	-0.63	0.397	23.77	-2.255	1.05	0.069
	Females	-0.566	0.32	58.567	-4.694	2.587	0.112

Table 19: Correlation of High VHF Band Density to SIR in S1 Zones

		r	R2	SE	Beta	SE	p
Total	Males	0.586	0.343	8.619	1.328	0.695	0.098
	Females	0.044	0.002	10.426	0.098	0.84	0.91
Squamous	Males	0.44	0.194	13.906	1.454	1.121	0.236
	Females	0.562	0.316	18.595	2.695	1.499	0.115
Adeno	Males	0.336	0.113	13.57	1.031	1.093	0.377
	Females	-0.323	0.105	13.124	-0.956	1.058	0.396
Large Cell	Males	-0.193	0.037	9.24	-0.388	0.745	0.618
	Females	-0.281	0.079	66.706	-4.161	5.377	0.464
Small Cell	Males	0.537	0.289	11.82	1.606	0.953	0.136
	Females	0.139	0.019	28.565	0.858	2.302	0.72
Undif. Cell	Males	0.215	0.046	16.776	0.787	1.352	0.579
	Females	0.215	0.046	16.776	0.787	1.352	0.579
Sarcoma	Males	-0.19	0.036	88.969	-3.679	7.171	0.624
	Females	0.039	0.002	132.37	1.095	10.669	0.921
Mesoth	Males	-0.243	0.059	30.414	-1.622	2.541	0.529
	Females	-0.414	0.172	74.488	-7.228	6.004	0.268

N= 9 for all groups; r= correlation coefficient

*=$p<0.05$ **=$p<0.01$

Table 20: Correlation of Low VHF Band Density to SIR in N2 Zones

		r	R2	SE	Beta	SE	p
Total	Males	0.021	0.001	9.434	0.057	1.039	0.958
	Females	-0.262	0.068	8.846	-0.699	0.975	0.497
Squamous	Males	-0.127	0.016	11.046	-0.411	1.217	0.746
	Females	-0.723	0.523	15.41	-4.703	1.698	0.028*
Adeno	Males	0.544	0.296	12.821	2.424	1.412	0.13
	Females	-0.755	0.57	14.774	-4.963	1.628	0.019*
Large Cell	Males	-0.217	0.047	19.005	-1.232	2.094	0.575
	Females	-0.543	0.295	28.939	-5.457	3.188	0.131
Small Cell	Males	0.503	0.253	7.868	1.334	0.867	0.168
	Females	-0.176	0.031	22.568	-1.175	2.486	0.651
Undif. Cell	Males	0.38	0.145	18.959	2.273	2.089	0.312
	Females	0.721	0.52	32.367	9.812	3.566	0.028*
Sarcoma	Males	-0.815	0.664	31.678	-12.98	3.49	0.007**
	Females	-0.234	0.055	111.53	-7.842	12.287	0.544
Mesoth	Males	-0.715	0.511	21.41	-6.379	2.359	0.030*
	Females	-0.567	0.321	58.501	-11.737	6.445	0.111

Table 21: Correlation of Low VHF Band Density to SIR in S1 Zones

		r	R2	SE	Beta	SE	p
Total	Males	0.627	0.393	8.287	3.435	1.614	0.071
	Females	0.144	0.021	10.327	0.776	2.012	0.711
Squamous	Males	0.507	0.257	13.349	4.049	2.601	0.164
	Females	0.574	0.33	18.403	6.657	3.585	0.106
Adeno	Males	0.257	0.066	13.92	1.907	2.712	0.505
	Females	-0.185	0.034	13.628	-1.324	2.655	0.633
Large Cell	Males	-0.04	0.002	9.41	-0.196	1.853	0.918
	Females	-0.241	0.058	67.448	-8.643	13.14	0.532
Small Cell	Males	0.701	0.491	9.998	5.063	1.948	0.035*
	Females	0.136	0.018	28.58	2.017	5.568	0.728
Undif. Cell	Males	0.203	0.041	16.82	1.795	3.277	0.601
	Females	0.279	0.078	23.258	3.482	4.531	0.467
Sarcoma	Males	-0.077	0.006	90.355	-3.608	17.603	0.843
	Females	-0.04	0.002	132.36	-2.726	25.787	0.919
Mesoth	Males	-0.307	0.094	29.841	-4.954	5.814	0.422
	Females	-0.401	0.163	74.876	-17.025	14.857	0.281

N= 9 for all groups; r= correlation coefficient

**=p<0.05 **=p<0.01*

Tower Distance Regression

Tower Distance Overview

When changing the independent variable from radioemission density to distance from a particular broadcast tower, it is important to realize that the perspective of analysis must change as well. When analyzing incidence of lung cancer in terms of radioemission density, a positive correlation indicates an analogous association between the variables. However, when substituting distance from a point source for density, the reverse is true: as distance increases, incidence resulting from exposure should decrease. Thus, the direction of the correlation should inverse, if the measure of distance is a reasonable surrogate measure of exposure to radioemission broadcasts.

As before in the radiowave density regressions for the individual census tracts, a natural log transformation of the SIR was performed to normalize the data, based on a plot of the residuals. For this regression, the predictor variable was the distance between the location of the broadcast towers and the population centroid of the individual census tract, and the dependent variable was the natural log of the SIR.

However, for the concentric distance zone analysis involving the distance zones around the broadcast towers, there was no transformation performed on the calculated SIR. Thus for each regression the dependent variable was the SIR calculated across each zone, while the predictor variable was the distance from the respective tower to the midpoint of the zone.

N2 Broadcast tower distance comparison

Beginning with the census tracts surrounding the N2 tower, two significant inverse associations were found. (Table 22) For males, the negative correlation was with the undifferentiated large cell group (p=.011). And in females the negative correlation was with the undifferentiated unspecified cell histogroup (p=.003).

After pooling the census tracts into the concentric zones around the N2 tower, there were four significant associations found within the histogroups. (Table 23) Two of these associations were positively correlated with SIRs in the concentric zones. One association was found in females with adenocarcinoma (p=.042), while the other was with cases of male sarcoma (p=.045). The remaining negative associations were both in males, specifically with adenocarcinoma (p=.012) and small cell (p=.030). Within the adenocarcinoma histogroup, it is important to note that the correlation was negative for males, yet positive for females.

S1 Broadcast Tower comparison

Stratified by census tracts surrounding the S1 tower, two significant inverse associations were found. (Table 24) Similar to the N2 tower, the negative correlation in females was found with the undifferentiated unspecified cell group (p=.012). In males the negative correlation was with adenocarcinoma (p=.048).

After substitution of the distance zones surrounding the S1 tower, there were three significant inverse associations found. (Table 25) All three negative correlations were found in males exclusively. They were with the squamous (p=.01), small cell (p=.048), and total cancer (p=.008) histogroups. As previously mentioned, there were no associations found in females.

Table 22: Correlation of Distance from N2 Tower to SIR in Census Tracts

		r	R2	SE	Beta	SE	p
Total	Males	-0.028	0.001	0.538	-0.001	0.003	0.652
	Females	0.016	0.001	1.002	0.001	0.006	0.799
Squamous	Males	0.052	0.003	0.869	0.004	0.005	0.395
	Females	-0.035	0.001	2.307	-0.008	0.014	0.570
Adeno	Males	-0.104	0.011	1.190	-0.012	0.007	0.090
	Females	0.106	0.011	2.106	0.022	0.013	0.086
Large Cell	Males	-0.098	0.010	1.960	-0.019	0.012	0.011*
	Females	0.052	0.003	2.645	0.013	0.016	0.402
Small Cell	Males	-0.058	0.003	1.580	-0.009	0.010	0.345
	Females	-0.062	0.004	2.498	-0.015	0.015	0.317
Undif. Cell	Males	-0.065	0.004	1.635	-0.011	0.010	0.292
	Females	-0.182	0.033	2.538	-0.046	0.015	0.003**
Sarcoma	Males	0.060	0.004	1.868	0.011	0.011	0.334
	Females	-0.036	0.001	1.743	-0.006	0.011	0.559
Mesoth	Males	-0.060	0.004	2.667	-0.016	0.016	0.332
	Females	0.032	0.001	2.126	0.006	0.013	0.602

Table 23: Correlation of Distance from N2 Tower to SIR in Distance Zones

		r	R2	SE	Beta	SE	p
Total	Males	-0.474	0.225	8.965	-0.456	0.346	0.236
	Females	0.206	0.042	9.231	0.184	0.356	0.624
Squamous	Males	-0.304	0.093	11.273	-0.340	0.435	0.464
	Females	0.482	0.232	20.941	1.088	0.808	0.227
Adeno	Males	-0.823	0.677	8.838	-1.209	0.341	0.012*
	Females	0.725	0.526	12.332	1.228	0.476	0.042*
Large Cell	Males	0.004	0.000	21.028	0.007	0.811	0.993
	Females	0.293	0.086	27.054	0.784	1.044	0.481
Small Cell	Males	-0.755	0.569	5.358	-0.582	0.207	0.030*
	Females	-0.060	0.004	24.629	-0.141	0.950	0.887
Undif. Cell	Males	-0.623	0.388	16.248	-1.223	0.627	0.099
	Females	-0.516	0.266	39.513	-2.250	1.524	0.190
Sarcoma	Males	0.717	0.514	31.416	3.055	1.212	0.045*
	Females	0.343	0.118	111.527	3.849	4.302	0.405
Mesoth	Males	0.434	0.188	29.708	1.352	1.146	0.283
	Females	0.355	0.126	68.237	2.452	2.632	0.388

N= 219 for all groups; r= correlation coefficient

**=p<0.05 **=p<0.01*

Table 24: Correlation of Distance from S1 Tower to SIR in Census Tracts

		r	R2	SE	Beta	SE	p
Total	Males	-0.045	0.002	0.538	-0.002	0.003	0.462
	Females	-0.035	0.001	1.001	-0.003	0.006	0.571
Squamous	Males	0.002	0.000	0.870	0.0002	0.005	0.969
	Females	-0.088	0.008	2.301	-0.019	0.014	0.154
Adeno	Males	-0.122	0.015	1.188	-0.014	0.007	0.048*
	Females	0.066	0.004	2.113	0.014	0.013	0.281
Large Cell	Males	-0.056	0.003	1.966	-0.011	0.012	0.368
	Females	0.046	0.002	2.646	0.012	0.016	0.459
Small Cell	Males	-0.063	0.004	1.580	-0.009	0.009	0.307
	Females	-0.077	0.006	2.495	-0.019	0.015	0.211
Undif. Cell	Males	-0.079	0.006	1.652	-0.012	0.010	0.203
	Females	-0.154	0.024	2.550	-0.038	0.015	0.012*
Sarcoma	Males	0.021	0.001	1.871	0.003	0.011	0.730
	Females	-0.041	0.002	1.743	-0.007	0.010	0.503
Mesoth	Males	-0.050	0.003	2.667	-0.013	0.016	0.417
	Females	0.041	0.002	2.125	0.008	0.013	0.511

Table 25: Correlation of Distance from S1 Tower to SIR in Distance Zones

		r	R2	SE	Beta	SE	p
Total	Males	-0.844	0.712	6.160	-0.916	0.238	0.008**
	Females	-0.294	0.086	10.631	-0.309	0.410	0.48
Squamous	Males	-0.837	0.700	8.838	-1.276	0.341	0.010*
	Females	-0.484	0.234	21.02	-1.097	0.811	0.225
Adeno	Males	-0.450	0.203	11.853	-0.565	0.457	0.263
	Females	0.182	0.033	11.857	0.208	0.457	0.665
Large Cell	Males	0.169	0.029	9.957	0.162	0.384	0.688
	Females	0.056	0.003	73.194	0.387	2.824	0.895
Small Cell	Males	-0.710	0.504	10.325	-0.984	0.398	0.048*
	Females	-0.458	0.210	27.653	-1.347	1.067	0.253
Undif. Cell	Males	-0.459	0.210	14.611	-0.713	0.564	0.253
	Females	-0.116	0.013	21.33	-0.235	0.823	0.785
Sarcoma	Males	0.210	0.044	94.32	1.915	3.638	0.618
	Females	0.128	0.016	135.741	1.660	5.236	0.762
Mesoth	Males	0.464	0.216	28.884	1.431	1.114	0.247
	Females	0.038	0.001	81.786	0.293	3.155	0.929

N= 8 for all groups; r= correlation coefficient

**=p<0.05 **=p<0.01*

Summary of Regression Results by Histogroup

This section summarized the results of all the regressions run for radiowave band density and distance from broadcast towers, sorted by histologic type. All three levels of analysis have been combined into a summary table, split by gender.

Table 26: Total Cancer Summary of Regression Results

Males

			r	R2	SE	Beta	SE	p-value
Census Tract	Density	FM	-0.152	0.023	0.559	-0.001	0	.025*
		High VHF	-0.046	0.002	0.566	-0.002	0.003	0.502
		Low VHF	-0.06	0.004	0.565	-0.009	0.011	0.376
	Distance- N2		-0.028	0.001	0.538	-0.001	0.003	0.652
	Distance- S1		-0.045	0.002	0.538	-0.002	0.003	0.462
GR	Density	FM	-0.447	0.2	19.693	-0.091	0.042	.042*
		High VHF	-0.119	0.014	21.856	-0.334	0.64	0.608
		Low VHF	-0.198	0.039	21.575	-1.795	2.035	0.389
Zone N2	Density	FM	0.562	0.316	7.803	0.171	0.095	0.115
		High VHF	0.268	0.072	9.091	0.295	0.402	0.486
		Low VHF	0.021	0	9.434	0.057	1.039	0.958
	Distance- N2		-0.474	0.225	8.965	-0.456	0.346	0.236
S1	Density	FM	0.374	0.14	9.86	0.048	0.045	0.321
		High VHF	0.586	0.343	8.619	1.328	0.695	0.098
		Low VHF	0.627	0.393	8.287	3.435	1.614	0.071
	Distance- S1		-0.844	0.712	6.16	-0.916	0.238	.008**

Females

			r	R2	SE	Beta	SE	p-value
Census Tract	Density	FM	0.01	0	0.94	0	0	0.878
		High VHF	-0.081	0.007	0.937	-0.007	0.006	0.234
		Low VHF	-0.248	0.062	0.911	-0.064	0.017	0.000**
	Distance- N2		0.016	0	1.002	0.001	0.006	0.799
	Distance- S1		-0.035	0.001	1.001	-0.003	0.006	0.571
GR	Density	FM	-0.062	0.004	25.944	-0.015	0.055	0.788
		High VHF	0.565	0.319	21.45	1.875	0.628	0.008**
		Low VHF	0.408	0.167	23.731	4.361	2.238	0.066
Zone N2	Density	FM	-0.09	0.008	9.128	-0.027	0.111	0.817
		High VHF	-0.187	0.035	9.003	-0.2	0.398	0.63
		Low VHF	-0.262	0.068	8.846	-0.699	0.975	0.497
	Distance- N2		0.206	0.042	9.231	0.184	0.356	0.624
S1	Density	FM	0.138	0.019	10.336	0.017	0.047	0.723
		High VHF	0.044	0.002	10.426	0.098	0.84	0.91
		Low VHF	0.144	0.021	10.327	0.776	2.012	0.711
	Distance- S1		-0.294	0.086	10.631	-0.309	0.411	0.481

Table 27: Squamous Cancer Summary of Regression Results

Males

			r	R2	SE	Beta	SE	p-value
Census Tract	Density	FM	-0.205	0.042	0.038	-0.001	0	.002**
		High VHF	-0.191	0.037	0.853	-0.015	0.005	.004**
		Low VHF	-0.355	0.126	0.812	-0.085	0.015	.000**
	Distance- N2		0.052	0.003	0.869	0.004	0.005	0.395
	Distance- S1		0.002	0	0.87	0.0002	0.005	0.969
GR	Density	FM	-0.42	0.177	29.858	-0.128	0.064	0.058
		High VHF	0.143	0.021	32.565	0.602	0.954	0.535
		Low VHF	-0.015	0	32.901	-0.208	3.103	0.947
Zone N2	Density	FM	0.416	0.173	10.128	0.149	0.124	0.266
		High VHF	0.125	0.016	11.048	0.163	0.488	0.748
		Low VHF	-0.127	0.016	11.046	-0.411	1.217	0.746
	Distance- N2		-0.304	0.093	11.273	-0.34	0.435	0.464
S1	Density	FM	0.292	0.085	14.812	0.054	0.068	0.445
		High VHF	0.44	0.194	13.906	1.454	1.121	0.236
		Low VHF	0.507	0.257	13.349	4.049	2.601	0.164
	Distance- S1		-0.837	0.7	8.838	-1.276	0.341	0.01*

Females

			r	R2	SE	Beta	SE	p-value
Census Tract	Density	FM	-0.205	0.042	0.851	-0.001	0	0.002**
		High VHF	-0.056	0.003	2.281	-0.012	0.014	0.406
		Low VHF	-0.061	0.004	2.281	-0.038	0.043	0.369
	Distance- N2		-0.035	0.001	2.307	-0.008	0.014	0.57
	Distance- S1		-0.088	0.008	2.3	-0.019	0.014	0.154
GR	Density	FM	0.156	0.024	32.716	0.048	0.07	0.499
		High VHF	0.575	0.33	27.103	2.431	0.794	0.006**
		Low VHF	0.466	0.217	29.308	6.343	2.764	0.033*
Zone N2	Density	FM	-0.32	0.103	21.138	-0.231	0.258	0.401
		High VHF	-0.595	0.354	17.936	-1.551	0.792	0.091
		Low VHF	-0.723	0.523	15.41	-4.703	1.698	0.028*
	Distance- N2		0.482	0.232	20.941	1.088	0.808	0.227
S1	Density	FM	0.589	0.347	18.163	0.161	0.083	0.095
		High VHF	0.562	0.316	18.595	2.695	1.499	0.115
		Low VHF	0.574	0.33	18.403	6.657	3.585	0.106
	Distance- S1		-0.484	0.234	21.02	-1.097	0.811	0.225

Table 28: Adenocarcinoma Summary of Regression Results

Males

			r	R2	SE	Beta	SE	p-value
Census Tract	Density	FM	-0.045	0.002	1.123	-0.001	0.001	0.509
		High VHF	0.024	0.001	1.124	0.002	0.007	0.725
		Low VHF	0.006	0	1.124	0.002	0.021	0.932
	Distance- N2		-0.104	0.011	1.19	-0.012	0.007	0.09
	Distance- S1		-0.122	0.015	1.188	-0.014	0.007	.048*
GR		FM	-0.287	0.083	23.05	-0.064	0.049	0.207
	Density	High VHF	-0.652	0.425	18.243	-2.004	0.534	.001**
		Low VHF	-0.526	0.277	20.467	-5.204	1.93	.014*
Zone N2		FM	0.663	0.44	11.437	0.327	0.14	0.052
	Density	High VHF	0.604	0.365	12.181	1.078	0.538	0.085
		Low VHF	0.544	0.296	12.821	2.424	1.412	0.13
	Distance- N2		-0.823	0.677	8.838	-1.209	0.341	.012*
		FM	0.019	0	14.39	0.003	0.066	0.961
S1	Density	High VHF	0.336	0.113	13.57	1.031	1.093	0.377
		Low VHF	0.257	0.066	13.92	1.907	2.712	0.505
	Distance- S1		-0.45	0.203	11.853	-0.565	0.457	0.263

Females

			r	R2	SE	Beta	SE	p-value
Census Tract	Density	FM	-0.071	0.005	2.06	-0.001	0.001	0.296
		High VHF	-0.005	0.002	2.063	-0.009	0.013	0.464
		Low VHF	-0.117	0.014	2.051	-0.066	0.038	0.084
	Distance- N2		0.106	0.011	2.106	0.022	0.013	0.086
	Distance- S1		0.066	0.004	2.113	0.014	0.013	0.281
GR		FM	0.056	0.003	29.104	0.015	0.062	0.808
	Density	High VHF	0.233	0.054	28.351	0.866	0.83	0.31
		Low VHF	0.21	0.044	28.503	2.511	2.688	0.362
Zone N2		FM	-0.578	0.334	18.392	-0.421	0.224	0.103
	Density	High VHF	-0.712	0.506	15.836	-1.875	0.699	0.032*
		Low VHF	-0.755	0.57	14.774	-4.963	1.628	0.019*
	Distance- N2		0.725	0.526	12.332	1.228	0.476	0.042*
		FM	0.04	0.002	13.86	0.007	0.064	0.919
S1	Density	High VHF	-0.323	0.105	13.124	-0.956	1.058	0.396
		Low VHF	-0.185	0.034	13.628	-1.324	2.655	0.633
	Distance- S1		0.182	0.033	11.857	0.208	0.457	0.665

Table 29: Undifferentiated Large Cell Summary of Regression Results

Males

			r	R2	SE	Beta	SE	p-value
Census Tract	Density	FM	-0.053	0.003	1.882	-0.001	0.001	0.433
		High VHF	-0.011	0	1.884	-0.002	0.012	0.869
		Low VHF	0.028	0.001	1.884	0.014	0.035	0.681
	Distance- N2		-0.098	0.01	1.96	-0.019	0.012	0.011*
	Distance- S1		-0.056	0.003	1.966	-0.011	0.012	0.368
GR								
	Density	FM	-0.218	0.048	32.665	-0.068	0.069	0.342
		High VHF	0.113	0.013	33.256	0.483	0.974	0.625
		Low VHF	0.026	0.001	33.459	0.36	3.156	0.91
Zone								
N2	Density	FM	0.0978	0.009	19.377	0.061	0.237	0.804
		High VHF	-0.083	0.07	19.403	-0.188	0.857	0.833
		Low VHF	-0.217	0.047	19.005	-1.232	2.094	0.575
	Distance- N2		0.004	0	21.028	0.007	0.811	0.993
		FM	0.055	0.003	9.403	0.006	0.043	0.889
S1	Density	High VHF	-0.193	0.037	9.24	-0.388	0.745	0.618
		Low VHF	-0.04	0.002	9.41	-0.196	1.853	0.918
	Distance- S1		0.169	0.029	9.957	0.162	0.384	0.688

Females

			r	R2	SE	Beta	SE	p-value
Census Tract	Density	FM	-0.081	0.007	2.605	-0.001	0.001	0.231
		High VHF	-0.057	0.003	2.609	-0.014	0.016	0.4
		Low VHF	-0.079	0.006	2.606	-0.057	0.049	0.244
	Distance- N2		0.052	0.003	2.645	0.013	0.016	0.402
	Distance- S1		0.046	0.002	2.646	0.012	0.016	0.459
GR								
	Density	FM	-0.079	0.006	58.435	-0.043	0.124	0.733
		High VHF	0.339	0.115	55.158	2.534	1.616	0.133
		Low VHF	0.179	0.032	57.673	4.315	5.44	0.437
Zone								
N2	Density	FM	-0.426	0.182	31.178	-0.474	0.381	0.253
		High VHF	-0.536	0.287	29.098	-2.159	1.285	0.137
		Low VHF	-0.543	0.295	28.939	-5.457	3.188	0.131
	Distance- N2		0.293	0.086	27.054	0.784	1.044	0.481
		FM	-0.237	0.056	67.528	-0.199	0.31	0.54
S1	Density	High VHF	-0.281	0.079	66.706	-4.161	5.377	0.464
		Low VHF	-0.241	0.058	67.448	-8.643	13.14	0.532
	Distance- S1		0.056	0.003	73.194	0.387	2.824	0.895

Table 30: Undifferentiated Small Cell Summary of Regression Results

Males

			r	R2	SE	Beta	SE	p-value
Census Tract	Density	FM	-0.256	0.066	1.453	-0.002	0.001	.000**
		High VHF	-0.11	0.012	1.494	-0.015	0.009	0.106
		Low VHF	-0.052	0.003	1.501	-0.021	0.028	0.446
	Distance- N2		-0.058	0.003	1.58	-0.009	0.01	0.345
	Distance- S1		-0.063	0.004	1.58	-0.009	0.009	0.307
GR	Density	FM	-0.287	0.082	27.146	-0.075	0.058	0.207
		High VHF	-0.312	0.097	26.925	-1.129	0.789	0.169
		Low VHF	-0.273	0.075	27.259	-3.186	2.571	0.231
Zone N2	Density	FM	0.876	0.767	4.398	0.257	0.054	0.002**
		High VHF	0.686	0.471	6.621	0.73	0.292	0.041*
		Low VHF	0.503	0.253	7.868	1.334	0.867	0.168
	Distance- N2		-0.755	0.569	5.358	-0.582	0.207	.030*
S1	Density	FM	0.559	0.312	11.623	0.095	0.053	0.118
		High VHF	0.537	0.289	11.82	1.606	0.953	0.136
		Low VHF	0.701	0.491	9.998	5.063	1.948	0.035*
	Distance- S1		-0.71	0.504	10.325	-0.984	0.398	.048*

Females

			r	R2	SE	Beta	SE	p-value
Census Tract	Density	FM	-0.132	0.017	2.462	-0.002	0.001	0.052
		High VHF	0.004	0	2.484	0	0.015	0.953
		Low VHF	-0.097	0.009	2.472	-0.066	0.046	0.152
	Distance- N2		-0.062	0.004	2.498	-0.015	0.015	0.317
	Distance- S1		-0.077	0.006	2.495	-0.019	0.015	0.211
GR	Density	FM	-0.282	0.079	32.195	-0.088	0.068	0.216
		High VHF	0.372	0.139	31.139	1.596	0.912	0.096
		Low VHF	0.202	0.041	32.863	2.782	3.1	0.381
Zone N2	Density	FM	0.085	0.007	22.841	0.063	0.279	0.827
		High VHF	-0.089	0.008	22.835	-0.237	1.009	0.821
		Low VHF	-0.176	0.031	22.568	-1.175	2.486	0.651
	Distance- N2		-0.06	0.004	24.629	-0.141	0.95	0.887
S1	Density	FM	-0.057	0.003	28.799	-0.019	0.132	0.884
		High VHF	0.139	0.019	28.565	0.858	2.302	0.720
		Low VHF	0.136	0.018	28.58	2.017	5.568	0.728
	Distance- S1		-0.458	0.21	27.653	-1.347	1.067	0.253

Table 31: Undifferentiated Unspecified Cell Summary of Regression Results

Males

			r	R2	SE	Beta	SE	p-value
Census Tract	Density	FM	-0.018	0.033	1.563	-0.002	0.001	.007**
		High VHF	-0.043	0.002	1.587	-0.006	0.01	0.523
		Low VHF	-0.015	0	1.589	-0.006	0.03	0.827
	Distance- N2		-0.065	0.004	1.635	-0.011	0.01	0.292
	Distance- S1		-0.079	0.006	1.652	-0.012	0.01	0.203
GR	Density	FM	-0.174	0.03	30.152	-0.049	0.064	0.45
		High VHF	-0.233	0.054	29.778	-0.911	0.872	0.309
		Low VHF	-0.197	0.039	30.021	-2.478	2.832	0.392
Zone N2	Density	FM	0.339	0.115	19.285	0.225	0.235	0.372
		High VHF	0.402	0.161	18.775	0.962	0.829	0.284
		Low VHF	0.38	0.145	18.959	2.273	2.089	0.312
	Distance- N2		-0.623	0.388	16.248	-1.223	0.627	0.099
S1	Density	FM	0.038	0.001	17.164	0.008	0.079	0.922
		High VHF	0.215	0.046	16.776	0.787	1.352	0.579
		Low VHF	0.203	0.041	16.82	1.795	3.277	0.601
	Distance- S1		-0.459	0.21	14.611	-0.713	0.564	0.253

Females

			r	R2	SE	Beta	SE	p-value
Census Tract	Density	FM	0.043	0.002	2.565	0.001	0.001	0.522
		High VHF	-0.02	0	2.567	-0.004	0.016	0.767
		Low VHF	-0.089	0.008	2.557	-0.063	0.048	0.191
	Distance- N2		-0.182	0.033	2.538	-0.046	0.015	.003**
	Distance- S1		-0.154	0.024	2.55	-0.038	0.015	.012*
GR	Density	FM	-0.013	0	52.609	-0.006	0.122	0.957
		High VHF	-0.354	0.126	49.199	-2.38	1.441	0.115
		Low VHF	-0.205	0.042	51.501	-4.425	4.857	0.374
Zone N2	Density	FM	0.541	0.293	39.271	0.816	0.479	0.132
		High VHF	0.695	0.483	33.583	3.792	1.483	0.038*
		Low VHF	0.721	0.52	32.367	9.812	3.566	0.028*
	Distance- N2		-0.516	0.266	39.513	-2.25	1.524	0.19
S1	Density	FM	0.113	0.013	24.064	0.033	0.11	0.772
		High VHF	0.261	0.068	23.38	1.348	1.884	0.498
		Low VHF	0.279	0.078	23.258	3.482	4.531	0.467
	Distance- S1		-0.116	0.013	21.33	-0.235	0.823	0.785

Table 32: Sarcoma Summary of Regression Results

Males

			r	R2	SE	Beta	SE	p-value
Census Tract	Density	FM	0.255	0.065	1.778	0.003	0.001	.000**
		High VHF	0	0	1.839	0	0.011	0.995
		Low VHF	-0.01	0	1.839	-0.005	0.034	0.883
	Distance- N2		0.06	0.004	1.868	0.011	0.011	0.334
	Distance- S1		0.021	0	1.871	0.003	0.011	0.73
GR	Density	FM	0.574	0.329	104.11	0.676	0.221	.007**
		High VHF	-0.024	0.001	127.06	-0.392	3.722	0.917
		Low VHF	0.184	0.034	124.92	9.637	11.782	0.424
Zone N2	Density	FM	-0.571	0.325	44.883	-1.007	0.548	0.109
		High VHF	-0.737	0.543	36.948	-4.706	1.632	0.024*
		Low VHF	-0.815	0.664	31.678	-12.98	3.49	0.007**
	Distance- N2		0.717	0.514	31.416	3.055	1.212	0.045*
S1	Density	FM	0.058	0.003	90.473	0.064	0.415	0.882
		High VHF	-0.19	0.036	88.969	-3.679	7.171	0.624
		Low VHF	-0.077	0.006	90.355	-3.608	17.603	0.843
	Distance- S1		0.21	0.044	94.32	1.915	3.638	0.618

Females

			r	R2	SE	Beta	SE	p-value
Census Tract	Density	FM	-0.031	0.001	1.776	0	0.001	0.645
		High VHF	0.1	0.01	1.768	0.016	0.011	0.139
		Low VHF	0.049	0.002	1.775	0.024	0.033	0.474
	Distance- N2		-0.036	0.001	1.743	-0.006	0.011	0.559
	Distance- S1		-0.041	0.002	1.743	-0.007	0.01	0.503
GR	Density	FM	-0.118	0.014	334.33	-0.367	0.711	0.611
		High VHF	0.784	0.615	208.99	33.702	6.122	.000**
		Low VHF	0.509	0.259	289.75	70.481	27.329	.018*
Zone N2	Density	FM	-0.086	0.007	114.3	-0.319	1.395	0.826
		High VHF	-0.183	0.034	112.78	-2.459	4.982	0.637
		Low VHF	-0.234	0.055	111.53	-7.842	12.287	0.544
	Distance- N2		0.343	0.118	111.53	3.849	4.302	0.405
S1	Density	FM	-0.055	0.003	132.27	-0.089	0.606	0.885
		High VHF	0.039	0.002	132.37	1.095	10.669	0.921
		Low VHF	-0.04	0.002	132.36	-2.726	25.787	0.919
	Distance- S1		0.128	0.016	135.74	1.66	5.236	0.762

Table 33: Mesothelioma Summary of Regression Results

Males

			r	R2	SE	Beta	SE	p-value
Census Tract	Density	FM	-0.046	0.002	2.723	0	0.001	0.494
		High VHF	-0.077	0.006	0.001	-0.019	0.017	0.255
		Low VHF	-0.085	0.007	2.716	-0.064	0.051	0.211
	Distance- N2		-0.06	0.004	2.667	-0.016	0.016	0.332
	Distance- S1		-0.05	0.003	2.667	-0.013	0.016	0.417
GR	Density	FM	-0.169	0.029	129.68	-0.206	0.276	0.464
		High VHF	0.678	0.459	96.736	11.388	2.834	.001**
		Low VHF	0.401	0.161	120.55	21.675	11.37	0.072
Zone N2	Density	FM	-0.388	0.151	28.217	-0.384	0.344	0.302
		High VHF	-0.63	0.397	23.77	-2.255	1.05	0.069
		Low VHF	-0.715	0.511	21.41	-6.379	2.359	0.03*
	Distance- N2		0.434	0.188	29.708	1.352	1.146	0.283
S1	Density	FM	-0.28	0.078	30.096	-0.106	0.138	0.465
		High VHF	-0.243	0.059	30.414	-1.622	2.541	0.529
		Low VHF	-0.307	0.094	29.841	-4.954	5.814	0.422
	Distance- S1		0.464	0.216	28.884	1.431	1.114	0.247

Females

			r	R2	SE	Beta	SE	p-value
Census Tract	Density	FM	-0.072	0.005	2.184	-0.001	0.001	0.289
		High VHF	-0.091	0.008	2.18	-0.018	0.013	0.179
		Low VHF	-0.084	0.007	2.183	-0.051	0.041	0.215
	Distance- N2		0.032	0.001	2.126	0.006	0.013	0.602
	Distance- S1		0.041	0.002	2.125	0.008	0.013	0.511
GR	Density	FM	-0.326	0.106	107.42	-0.343	0.228	0.15
		High VHF	-0.457	0.209	101.07	-6.626	2.96	.037*
		Low VHF	-0.484	0.234	99.41	-22.61	9.376	.026*
Zone N2	Density	FM	-0.432	0.187	64.034	-0.992	0.782	0.245
		High VHF	-0.566	0.32	58.567	-4.694	2.587	0.112
		Low VHF	-0.567	0.321	58.501	-11.737	6.445	0.111
	Distance- N2		0.355	0.126	68.237	2.452	2.632	0.388
S1	Density	FM	-0.469	0.22	72.286	-0.465	0.331	0.203
		High VHF	-0.414	0.172	74.488	-7.228	6.004	0.268
		Low VHF	-0.401	0.163	74.876	-17.025	14.857	0.281
	Distance- S1		0.038	0.001	81.786	0.293	3.155	0.929

Discussion

The current investigation sought to examine a potential association between lung cancer incidence and radioemission density in the Portland metropolitan area. It also attempted to identify areas of excess incidence irrespective of radioemission densities. It was anticipated that by using three disparate classifications of geographic exposure, any underlying association might be revealed. Because of this study, baseline information about the overall incidence of lung cancer in the Portland metro area has been established, potentially to serve as the foundation of future research and a source for comparison studies.

Case Classification and Potential Confounding

Overall, the percentage distribution by histologic types within this dataset is consistent with comparable studies of lung cancer over the similar time period. For most of the histologic groups in this investigation, the percentage of cases are similar to those reported in the Third National Cancer Survey (1969-1971). The exception to this was the proportion of adenocarcinoma.

With the exception of smoking, there does not appear to be excess confounding within the dataset by tuberculosis, asthma, or COPD, based on comparison of relative proportions of these variables to other reported studies of lung cancer. Epidemiological studies of host factors that are considered to contribute to the risk of lung cancer report similar percentages of cases with a prior diagnosis of tuberculosis, asthma, and COPD. (Samet 1997, Tockman 1994)

According to these other surveys, there seems to be far fewer cases of adenocarcinoma within this dataset. Adenocarcinomas are the most predominant histologic cell group among non-smokers, estimated in one study to represent 35% of lung cancer cases. (Mayo et al 1994) But for this investigation, cases of adenocarcinoma represented barely 20% of the total cases. It is quite plausible that with a higher percentage of smokers within the dataset, any effects resulting from exposure to RW might be masked or obscured from discovery.

No adjustment for smoking was made within the dataset, as the information about smoking in the population at risk was not readily available. It was decided that stratification by smoking status would have reduced the sample size and extended the analysis period. Therefore, no adjustment was made.

The proportion of smokers within this dataset is far higher than one would expect in the general U.S. population. According to the U.S. Public Health Service Office on Smoking and Health, in 1975 an estimated 60% of men and 21% of women over the age of 65 were either current or former smokers. The proportion of smokers was somewhat higher among younger men and women, but not above 78% for men and 55% for women. (U.S. Public Health Service 1979) For this dataset, smokers comprised 93.5% of the total overall cases of lung cancer with known smoking status. Among men, smokers represented 97.0% of all cases, while for women 81.1% of all cases were reported to have smoked.

This is consistent with other studies relating smoking to lung cancer. In one study by Geddes et al. of almost 300 cases, overall 98% of the tumors were found in smokers. Divided by histologic type, 100% of small cell, 98% of squamous cell, and 96% of

adenocarcinomas were found in smokers. For non-smokers, adenocarcinomas made up approximately 75% of cases of lung cancer in both men and women. (Churg 1994). And according to the U.S. Public Health Service Office on Smoking and Health, it is estimated that roughly 90% of all lung cancer cases can be attributed to smoking, but only 10% of smokers will develop a bronchial malignancy. (U.S. Public Health Service 1979)

Among males in this dataset, similar rates of smoking were seen in all histologic groups, with lower proportions among sarcoma and mesothelioma groups. For females, the overall proportion of smokers was lower than males, reflecting the lower incidence of smoking among females compared to males. This probably contributed to the lower proportion of female smokers for the adenocarcinoma group, while for overall cancers in females, this was the highest proportion of cases. The proportions of female smokers for squamous, undifferentiated large cell, and undiff. small cell groups were similar to males. But among all other histologic groups the rates were lower for females.

The case classification within the database is consistent with published studies. The potential confounding of asthma, tuberculosis, and COPD appears minimized. However, the potential for smoking as a confounder is substantial, due to the higher than expected proportions of smokers within the dataset. Geographic variations in the prevalence of smokers within the database could have obscured the effects of radiowave exposure. Without information on the prevalence of smoking for the larger population at risk, any adjustment was considered beyond the scope of this analysis.

Radiowave density analysis

The intent of investigation was to see if there was an incidence gradient for lung cancer that followed the radiowave emission density gradient, as measured across the Portland-Vancouver metropolitan area. Such an investigation also might have identified areas of excess incidence irrespective of radiowave densities. Although significant associations were found between radiowave emission density and SIRs at both the census tract and geographic region levels of analysis, there is a substantial lack of agreement in these associations.

Many of the associations with radiowave emission density are negatively correlated to the SIRs, in contrast to the proposed exposure model. For the FM band, six of the nine significant associations were negatively correlated to the band density. Similarly, five of the eleven associations with the High VHF band were negative. And for the Low VHF band, eight of the eleven significant associations were negative.

The relative strength of these associations across the radiowave bands is also called into question. Only a few associations within histogroups are repeated across levels of analysis.

And even these associations are inconsistent within the same gender. Males cases of undifferentiated small cell were negatively correlated to the FM band at the census tract level, but positively correlated at the N2 tower distance zone level of analysis.

Variations by gender can also be found within the same histogroup for the same radiowave band. For both the High VHF and Low VHF bands, cases with squamous cell type were correlated by gender in opposite directions. The association with males was significantly negative at the census tract level, while in females the association was

positive when analyzed by geographic region, and negative when analyzed by the N2 tower zones.

In short, the regression analysis results based on SIRs developed for census tracts, geographic regions, and the tower distance zones with regard to radiowave emission densities are contradictory and inconclusive. There is no indication overall of a pattern of risk consistent with the radiowave band density gradient. At the census tract level, substantial sampling variation may very well have been a limiting factor. Moreover, as for the geographic regions, they are an arbitrary construct of census tracts based neither on distance nor density measures for an exposure source, and may not be an appropriate measurement tool for this analysis.

Thus it appears that there is a substantive lack of agreement in the correlations between radiowave density and the incidence of lung cancer.

Distance from tower

When changing the independent variable from radioemission density to distance from a particular broadcast tower, it is important to realize that the perspective of analysis must change as well. When analyzing incidence of lung cancer in terms of radioemission density, a positive correlation indicates an analogous association between the variables. But when substituting distance from a point source for density, the reverse is true: as distance increases, incidence resulting from exposure should decrease. Thus, the direction of the correlation should reverse, if the measure of distance is a reasonable surrogate measure of exposure to radioemission broadcasts.

As a surrogate measure of density, the distance from each of the broadcast towers to the population centroid of the census tract for each case was anticipated to reflect any findings based on actual density, should any associations be found. This distance analysis allowed the investigation to target specific broadcast sites, not just overall exposure. This distance measurement was performed both for the individual census tracts and for concentric distance zones.

The direction of the associations with the broadcast towers varied between the towers. For the N2 tower, six significant associations were found between SIR and distance from tower at either the census tract or distance zone level of analysis. Four of these associations were inverse relationships. With regard to the S1 tower, all five of the significant associations were negatively correlated with the SIR by histogroup.

The direction and constancy of the associations with the S1 tower are consistent with the exposure model hypothesis. But for the N2 tower, this support is absent. Therefore the dissimilarity in the direction of the associations between the towers weakens this argument.

The relative strength of the possible correlations to distance from the towers is debatable. For both the N2 and S2 towers, there were no concurrent significant associations within the same histogroup across the census tract and distance zone levels of analysis, regardless of gender. Again, the support for the model is weak.

With one exception, there were no correlations found within individual histogroups that were shared by males and females. The one histogroup that did have significant associations in both genders was adenocarcinoma in the distance zones surrounding the N2 tower, but the direction of these associations were in opposition.

Thus even though correlations were found within a group, their relevance to the overall model of exposure is minimized.

Due to the inconsistent significant outcomes between the census tract and zone analyses for each tower site, it is suggested that none of the correlations is biologically significant. It is reasonable to expect that hypothetical associations within histogroups would be evident at both levels of analysis for a specific tower site. Such associations should be similar in direction as well as significance. And these associations would reasonably be found in both males and females. Based on the results from the tower distance analysis, the inconsistencies in direction as well as within histogroups and genders suggest that the observed significant associations are subject to dispute. Once again, the biologic plausibility of the association is suspect. It is not possible with this data, therefore, to define a correlation between proximity to the broadcast sites and the incidence of lung cancer.

Reconciliation of Density to Distance measures

Rather than attempting to reconcile the disparate results from the radioemission density and distance measures, it is recognized that it the overall tone of conflicting results probably renders the individual correlations biologically non-significant, despite meeting statistical thresholds. When the associations were significant, they were frequently contradictory, either by gender within histogroups or across the levels of analysis.

As an example, the summary results of two histogroups stand out. Among males with small cell carcinoma, the correlations were positive to FM and High VHF density,

and negative to both towers for distance. These results support the model of exposure being associated with increased incidence of lung cancer.

However among females with adenocarcinoma, the directions of the significant associations were reversed. For the High VHF and Low VHF radiowave densities, the correlation was negative. Likewise, the correlation to the N2 tower was positive. These results contradict the proposed model of exposure.

It was anticipated that combining the analytical measures of radioemission density and tower distance side-by-side would permit investigation of the research question from two differing perspectives. Any analogous results could then be further investigated and reconciled with the proposed model of exposure.

Instead, it appears that the use of multiple investigative perspectives did not clarify the associations found within the dataset. Rather, they have served to produce contradictory information about the direction and relative strengths of the associations. Being unable to reconcile the results of the various perspectives prevented the demonstration of an association between radiowave exposure and the incidence of lung cancer.

It appears that the question is not whether or not an association exists, but whether sufficient tools are available to adequately investigate the subject and provide an answer. To this end, it is anticipated that this investigation has established a baseline for further research into lung cancer incidence in the Portland-Vancouver metropolitan area.

Limitations of Study Design

It is important to discuss the limitations of this study, and analyze their potential impact on the results and recommendations.

First are the usual caveats attached to secondary data analysis. As secondary data, there was no opportunity to confirm the diagnosis through independent review of pathology slides, during either the initial data collection or the current analysis. The analysis was also limited to the variables contained within the original dataset, precluding additional lines of inquiry or elaboration of a given variable.

Second, spurious associations due to chance may have obscured the correlations. Given the number of analyses performed (256), it is possible that some of the significant findings will be due to chance. Based on a significance level of $p < 0.05$, it can be inferred that there will be 13 (5%) associations expected purely by chance. With 43 (16.8%) statistically significant associations identified through the study, it is reasonable to expect that approximately two thirds of the associations are legitimate. It cannot be ascertained, however, which of the associations identified are accurate, nor the direction of the suspect associations.

Third, the use of census tracts as a unit of analysis may have led to the rejection of the null hypothesis less frequently than it should have, based on the discreteness of the data. Due to the conservatism of the test, this remains a possibility. (Wakeford 1987 in Bithell and Stone 1989)

Fourth, population migration trends over the study period may have diluted the case identification for this study. It is believed that case ascertainment for the study period was very close to 100%, for persons living within the study area. However, there

is the possibility that some potential cases moved away following exposure but prior to diagnosis. Additional cases may have moved into the study area and settled at a different geographic location than the undiagnosed emigrant cases. The net result of this movement would be the dilution of differences in lung cancer due to radioemission exposure. If any significant associations were then found, they would be in spite of this migration.

Lastly, there are two concerns raised regarding exposure to radiowave emissions within the context of this investigation. First is the actual intensity of the exposure. The second has to do with the duration of the exposure. Both are important issues to address and understand, for their potential impact on the results.

First, exposure densities for the population at large could only be estimated. As mentioned, exposure values were estimates based on 810 field strength measurements from 38 locations at one point in time. Thus, these exposure values are only a surrogate measure of the actual exposure by all persons within the study area. They should be considered relative indicators of exposure differences, rather than absolute exposure measurements, for persons closer to a point source versus persons further away. Nonetheless, it can be presumed that, on average, residents in higher exposure areas will receive higher doses of radiowave emissions.

Second the duration of exposure for the population is unknown. For each case, the "census tract" variable indicated the residential census tract reported at the time of diagnosis. The actual duration of residence at the specific census tract was unknown. We are unable to know definitively the period of exposure, either for cases or for the

general population. The density measure therefore is unable to truly measure past exposure for cases.

Investigation of the literature revealed that these limitations are typical of investigations into large populations exposed to non-ionizing radiation. (Coleman and Beral 1988) Exposure levels are frequently below regulated levels for the vast majority of populations, making it difficult to compare exposure levels between studies. Moreover, due to the latency period of lung cancers, laboratory investigations utilize much higher levels of exposure to hasten carcinogenesis, limiting their comparability of results.

One criticism to the use of this distance zone style of analysis is the arbitrariness of the size of the region to consider. (Bithell and Stone 1989) By grouping census tracts into the concentric distance zones, we have potentially introduced an element of subjectivity into the analysis. The use of a crude Euclidean distance might otherwise function as a quantitative variable, since area increases as the square of distance. This potentially gives more weight to the most distant zones. However, because there are multiple sources of exposure across the study area, this distance measurement is the least-problematic method of identifying associations to individual sources or sites. (Shaddick and Elliott 1996)

Another potential criticism of this study is the lack of true exposure information. We do not have the actual radioemission density information for the exposure period of time prior to the study period, the very period of exposure that we are seeking to investigate. The EPA measurements of radioemission densities were made in 1977, independently coinciding with the end of the 15-year study period.

What is constant is the pattern of exposure for the general population. The original broadcast towers were erected in the 1950's, and were still in place when the EPA made its recordings. Thus, the relative exposure patterns for the community did not change from the 1950's through the end of the study period.

The broadcast strengths from the towers of the respective radio and television bands have been reasonably constant over time. Most of the broadcast stations began broadcasting from the towers at about the time they were built in the early 1950's, and continued to be broadcast with their original power and polarization until late in the 1970's. Thus, the strengths of exposure can reasonably be presumed to have been constant before and during the study period.

It is reasonable to conclude, therefore, that use of the 1977 radioemission density measurements is acceptable to use within the scope of this study.

Strengths of Study Design

An effective analysis depends on the complete ascertainment of cases. In this case, it is believed that almost all of the cases of lung cancer in the Portland metropolitan area were included in this analysis. Such complete recording of cases reduces the potential biases introduces from the exclusive use of tumor registry data.

Secondly, the calculation of rates and ratios within this investigation required accurate knowledge of population sizes. The utilization of census population numbers from the midpoint of the study period confers perhaps the highest level of accuracy possible for a study of such a large urban population. The use of the midpoint as the

population reference point in the calculation of annual rates reduces the impact of population fluctuations over the study time period.

Thirdly, both the pattern and relative strength of radioemission exposures remained remarkably stable for the metropolitan community throughout the probable exposure period and subsequent study period, as mentioned above. Although unable to record actual radioemission exposures, the consistency of both pattern and strength of exposure make this a reasonable surrogate measurement. This is one of the characteristics that strengthen the results of this investigation.

Future Directions

The study was unable to identify through radiofrequency emission density measurements a relationship between the broadcast bands and risk of lung cancer. The statistical analysis does not support a consistent correlation between exposure and lung cancer incidence. Although statistically significant associations were found for particular gender-specific histologic groups, these correlations did not manifest a consistent pattern. Due to the ambiguity inherent in the results, any interpretation of these findings must be treated with caution. No direct evidence was found to support efforts to regulate population exposure levels for radio and television transmissions.

The absence of evidence for a consistent correlation between radiowave density exposure and lung cancer incidence does not exclude the possibilities for significant effects on other types of cancer risks.

Conclusion

No direct evidence of an association between radiofrequency emission density and risk of lung cancer was found in this study. Nevertheless, the inconsistent results cannot be considered as support for a negative finding. There was no excess confounding identified, based on the variables contained within the dataset and compared to published literature. There were no trends of association to radiofrequency emission density seen across the various methods of analysis used in this study, although some associations were consistent with the proposed model. It is believed that the results of this study are insufficient to demonstrate an association between radiofrequency emission density and the incidence of lung cancer. It is urged that caution be taken in the interpretation of these results, perhaps instead using them as a baseline for further research. Due to the lack of consistency in the results, no recommendations regarding exposure standards or regulations can be made at this time.

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Tables and Figures

Table 34: Database Variable Key
1963-1977 Portland Metropolitan Lung Cancer Incidence Study

Columns	*Variable*
1-5	Individual identification number
6-7	County of Residence
8-11	Metropolitan area census tract number
12	Census tract urbanicity
13-15	Metropolitan census tract socioeconomic score
16	Metropolitan census tract grouping, socioeconomic
17-18	Metropolitan census tract group, geographic region
19	Gender
20	Race or ethnic group
21-23	Age at diagnosis, at last birthday
24	Age group
25-28	Date of diagnosis (MMYY)
29	Primary tumor site
30	Primary site, side
31-32	Tumor cell type
33	Stage of disease at initial diagnosis
34	Family history of cancer
35	Spouse history of cancer
36-37	Smoking history
38-39	Smoking duration
40-42	Pack-years of cigarette smoking
43	History of asthma
44	History of COPD (emphysema, bronchitis)
45	History of tuberculosis
46	History of diabetes
47	Other cancers
48	History of alcoholism
49-51	Industrial classification
52-54	Primary occupational classification
55	Retirement
56	Number of hospitals from which case report obtained
57	Death certificate available
58-59	Year of death

Table 35: Lung Cancer Diagnosis Field by Tumor Cell Type

00	unknown or clinical diagnosis only
05	hamartoma alone
10	carcinoma only, NOS
11	squamous cell ca., undifferentiated intermediate cell ca.
12	alveolar cell ca., undiff. large cell ca.
13	alveolar cell ca., undiff. small cell ca.
14	alveolar cell ca., undiff. unspec. ca.
15	squam. cell ca., undiff. large cell ca., undiff. small cell ca.
16	adenoca., undiff. large cell ca., alveolar cell ca.
17	adenoca., undiff. large cell ca., clear cell ca.
20	squam. cell carcinoma
21	squam. cell ca., adenoca., alveolar cell ca.
22	squam. cell ca., adenoca., undiff., unspec. ca.
23	squam. cell ca., adenoca., undiff. large cell ca.
24	squam. cell ca., adenoca., undiff. small cell ca.
25	squam. cell ca., adenoca., alveolar cell ca., mesothelioma
26	squam. cell ca., sarcoma
27	adenoca., sarcoma
28	small cell undiff. ca., sarcoma
29	adenoca. carcinoid type
30	adenocarcinoma
31	adenocanthoma (adenoca. with squamous metaplasia)
32	undiff. large cell ca. with squamous metaplasia
33	alveolar cell (bronchiolar) carcinoma
34	bronchial carcinoid
35	bronchial adenoma
36	adenoca., clear cell type
37	bronchial adenoma, adenocarcinoma
38	bronchial adenoma, alveolar cell ca., undiff. small cell ca.
39	bronchial adenoma, squamous cell ca.
40	undiff. large cell ca.
41	undiff. large cell ca. with squamous metaplasia
42	undiff. large cell ca., clear cell ca.
43	alveolar cell ca. with squamous metaplasia
45	undiff. clear cell ca.
46	mesothelioma, alveolar cell ca.
47	mesoth., adenoca., and alveolar cell ca.
48	mesoth., adenoca., and undiff. large cell ca.
50	undiff. small cell ca.
51	undiff. small cell ca. with squamous metaplasia
52	undiff. small cell ca., undiff. unspec. ca.
55	undiff. intermediate cell ca.

56	undiff. spindle cell ca.
60	undiff. carcinoma, type unspecified
61	undiff. carcinoma, lymphoepithelioma type
70	*blank*
71	carcinosarcoma with undiff. large cell ca.
72	carcinosarcoma
73	carcinosarcoma with adenocarcinoma
74	melanoma
75	embryonal cell carcinoma or teratocarcinoma
76	blastoma
77	rhabdomyosarcoma
78	mesoth., sarcoma
79	mesoth., squamous cell ca.
80	mesoth.
81	mesoth., adenoca.
82	lymphoma or lymphosarcoma
83	fibrolymphosarcoma
84	fibrosarcoma
85	neurosarcoma
86	neurofibrosarcoma
87	leiomyosarcoma
88	undiff. sarcoma
89	*blank*
90	adenosquamous carcinoma
91	adenoca., undiff. large cell ca.
92	adenoca., undiff. small cell ca.
93	adenoca., alveolar cell ca.
94	squamous cell ca., undiff. large cell ca.
95	squamous cell ca., undiff. small cell ca.
96	squamous cell ca., alveolar cell ca.
97	mixed undiff. large cell and small cell ca.
98	adenoca., undiff. unspec. ca.
99	squamous cell ca., undiff. unspec. ca.

Table 36: Histologic groups, by diagnosis code

Squamous cell : 11, 15, 20, 21, 22, 23, 24, 25, 26, 39, 79, 90, 94, 95, 96, 99

Adenocarcinoma: 12, 13, 14, 16, 17, 21, 22, 23, 24, 25, 27, 29, 30, 31, 33, 36, 37, 38, 42, 43, 45, 46, 47, 48, 73, 81, 90, 91, 92, 93, 96, 98

Undiff. large cell : 12, 15, 16,17, 23, 32, 40, 41, 42, 48, 71, 91, 94, 97

Undiff. small cell : 13, 15, 24, 28, 38, 50, 51, 52, 56, 92, 95, 97

Undiff. Unspecified cell: 10, 11, 14, 22, 52, 55, 60, 61, 76, 98, 99

Sarcomas: 26, 27, 28, 71, 72, 73, 77, 78, 82, 83, 84, 85, 86, 87, 88

Mesothelioma: 25, 46, 47, 48, 78, 79, 80, 81

Other: [not included in analysis] 00, 74, 75

Number of malignant cell types

Single: 10, 20, 29, 30, 31, 32, 33, 36, 37, 39, 40, 41, 43, 45, 50, 51, 55, 56, 60, 61, 72, 74, 75, 76, 77, 80, 82, 83, 84, 85, 86, 87, 88

Double: 11, 12, 13, 14, 26, 27, 28, 38, 42, 46, 52, 71, 73, 78, 79, 81, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99

Triple: 15, 16, 17, 21, 22, 23, 24, 47, 48

Quadruple: 25

Table 37: Census Tract Groupings by Geographic Region

County	Region Name	Number	Census Tracts											
Multnomah	Northwest	1	43.00	70.00	71.00									
	West Hills	2	46.01	46.02	58.00	60.01	60.02	61.00	68.01	68.02	69.00			
	Southwest	3	62.00	63.00	64.00	65.01	65.02	66.01	66.02	67.01	67.02			
	Downtown	4	45.00	47.00	48.00	49.00	50.00	51.00	52.00	53.00	54.00	55.00	56.00	57.00
			59.00											
	Peninsula	5	35.01	35.02	38.01	38.02	38.03	39.01	39.02	40.01	40.02	41.01	41.02	42.00
			44.00	72.00										
	North Central	6	22.01	22.02	23.01	23.02	24.01	24.02	33.01	33.02	34.01	34.02	36.01	37.01
			37.02											
	Central	7	10.00	11.01	11.02	12.01	12.02	20.00	21.00					
	South Central	8	1.00	2.00	3.01	3.02	4.01	4.02	5.01	5.02	7.02	8.02	9.02	86.00
			87.00	88.00										
	Southeast	9	7.01	8.01	9.01	13.01	13.02	14.00	15.00	16.01	16.02	17.01	17.02	18.01
			18.02	19.00										
	East Southeast	10	6.01	6.02	82.01	82.02	83.00	84.00	85.00	89.00	90.00	91.00	92.01	92.02
			97.01	97.02	98.01	98.02								
	Northeast	11	25.01	25.02	26.00	27.01	27.02	28.01	28.02	30.00	31.00	32.00	36.02	36.03
			74.00	75.00										
	East Northeast	12	29.01	29.02	29.03	73.00	76.00	77.00	78.00	79.00	80.01	80.02	81.00	93.00
			94.00	95.00										
	East	13	96.01	96.02	99.00	100.00	101.00	102.00	103.00	104.01	104.02	105.00		
Clackamas	Northwest	21	201.00	202.00	203.00	204.00	205.00	206.00	207.00	227.00				
	North Central	22	208.00	209.00	210.00	211.00	212.00	213.00	214.00	215.00	216.00	217.00	218.00	219.00
			220.00	221.00	222.00									
	Central	23	223.00	224.00	225.00	226.00	230.00	231.00						
	East	24	232.00	233.00	234.00	235.00	236.00	242.00	243.00					
	Southwest	25	228.00	229.00	237.00	238.00	239.00	240.00	241.00					
Washington	Northeast	31	301.00	302.00	303.00	304.00	305.00	310.00	311.00	312.00	313.00	314.01	314.02	315.00
			316.00	317.00	318.00									
	Southeast	32	306.00	307.00	308.00	309.00	319.00	320.00	321.00	322.00	323.00			
	Central	33	324.00	325.00	326.00	328.00	329.00	330.00	331.00	332.00	333.00			
	Northwest	34	327.00	334.00	335.00	336.00								
Clark Co., WA	West Vancouver	81	410.01	419.00	420.00	421.00	422.00	423.00	424.00	425.00				
	East Vancouver	82	416.00	417.00	418.00	426.00	427.00	428.00	429.00	430.00	431.00			
	NE Suburbs	83	410.02	411.01	411.02	412.00								
	SE County	84	405.02	405.03	406.00	413.00	414.00	415.00						
	North County	85	401.00	402.00	403.00	404.00	405.01	407.00	408.00	409.00				

Table 38: **Census tract groupings based on distance from N2 tower site to census tract population centroid.**

Distance (km)	Zone	Census Tracts							
0-4	1	45.00	46.01	46.02	47.00	68.01	69.00	301.00	302.00
		303.00							
4-8	2	10.00	11.01	11.02	21.00	22.01	22.02	23.01	23.02
		24.01	24.02	33.02	34.01	34.02	35.01	35.02	37.02
		38.02	38.03	39.01	39.02	40.01	40.02	41.02	42.00
		43.00	44.00	48.00	49.00	50.00	51.00	52.00	53.00
		54.00	55.00	56.00	57.00	58.00	59.00	60.01	60.02
		61.00	62.00	65.01	65.02	66.01	66.02	67.01	67.02
		68.02	70.00	304.00	305.00	310.00	311.00	312.00	313.00
		314.01	314.02	315.00					
8-12	3	1.00	2.00	3.01	3.02	4.01	4.02	8.01	8.02
		9.01	9.02	12.01	12.02	13.01	13.02	14.00	15.00
		18.01	18.02	19.00	20.00	25.01	25.02	26.00	27.01
		27.02	28.01	28.02	30.00	31.00	32.00	33.01	36.01
		36.02	36.03	37.01	38.01	41.01	63.00	64.00	72.00
		74.00	75.00	203.00	209.00	306.00	307.00	308.00	309.00
		316.00	317.00	318.00					
12-16	4	5.01	5.02	6.01	6.02	7.01	7.02	16.01	16.02
		17.01	17.02	29.01	29.02	29.03	73.00	76.00	77.00
		78.00	79.00	80.01	81.00	82.01	82.02	83.00	86.00
		87.00	88.00	201.00	202.00	204.00	208.00	210.00	211.00
		212.00	213.00	214.00	215.00	216.00	319.00	320.00	323.00
		324.00	417.00	418.00	419.00	420.00	421.00	422.00	423.00
		424.00	425.00	426.00	427.00	428.00	429.00		
16-20	5	71.00	80.02	84.00	85.00	89.00	90.00	91.00	92.01
		92.02	93.00	94.00	95.00	97.01	205.00	206.00	217.00
		218.00	219.00	220.00	221.00	222.00	321.00	325.00	326.00
		410.01	410.02	411.01	412.00	416.00	430.00	431.00	
20-24	6	96.01	96.02	97.02	98.01	98.02	101.00	102.00	207.00
		223.00	224.00	225.00	227.00	322.00	327.00	329.00	408.00
		409.00	411.02	413.00					
24-28	7	99.00	100.00	103.00	104.01	226.00	232.00	328.00	330.00
		332.00	407.00	414.00					
28-32	8	228.00	229.00	230.00	231.00	233.00	331.00	333.00	404.00
		405.03	406.00	415.00					
32+	9	104.02	105.00	234.00	235.00	236.00	237.00	238.00	239.00
		240.00	241.00	242.00	243.00	334.00	335.00	336.00	401.00
		402.00	403.00	405.01	405.02				

Table 39: **Census tract groupings based on distance from S1 tower site to census tract population centroid.**

Distance (km)	Zone	Census Tracts							
0-4	1	10.00	46.01	46.02	52.00	53.00	54.00	55.00	56.00
		57.00	58.00	59.00	60.01	60.02	61.00	62.00	65.02
		66.01	66.02	67.01	67.02	68.01	68.02	69.00	
4-8	2	1.00	2.00	3.01	3.02	4.01	4.02	8.01	8.02
		9.01	9.02	11.01	11.02	12.01	12.02	13.01	13.02
		14.00	15.00	18.02	19.00	20.00	21.00	22.01	22.02
		23.01	23.02	24.01	24.02	25.01	25.02	26.00	27.02
		33.02	34.01	34.02	35.01	35.02	44.00	45.00	47.00
		48.00	49.00	50.00	51.00	63.00	64.00	65.01	87.00
		88.00	201.00	208.00	209.00	210.00	212.00	301.00	302.00
		303.00	304.00	305.00	306.00	313.00			
8-12	3	5.01	5.02	6.01	6.02	7.01	7.02	16.01	16.02
		17.01	17.02	18.01	27.01	28.01	28.02	29.01	29.02
		29.03	30.00	31.00	32.00	33.01	36.01	36.02	36.03
		37.01	37.02	38.01	38.02	38.03	39.01	39.02	40.01
		40.02	41.02	70.00	74.00	75.00	76.00	82.01	83.00
		84.00	85.00	86.00	202.00	203.00	204.00	205.00	211.00
		213.00	214.00	215.00	216.00	218.00	307.00	308.00	309.00
		310.00	311.00	312.00	314.01	314.02	315.00	319.00	
12-16	4	41.01	42.00	43.00	72.00	73.00	77.00	78.00	79.00
		80.01	80.02	81.00	82.02	89.00	90.00	91.00	92.01
		92.02	93.00	94.00	95.00	97.01	206.00	217.00	219.00
		220.00	221.00	222.00	316.00	317.00	318.00	320.00	424.00
		426.00	428.00						
16-20	5	96.01	96.02	97.02	98.01	98.02	102.00	207.00	223.00
		224.00	225.00	226.00	227.00	321.00	323.00	324.00	410.02
		411.01	412.00	416.00	417.00	418.00	419.00	420.00	421.00
		422.00	423.00	425.00	427.00	429.00	430.00	431.00	
20-24	6	71.00	99.00	100.00	101.00	103.00	104.01	232.00	322.00
		325.00	326.00	408.00	410.01	411.02	413.00	414.00	
24-28	7	228.00	229.00	230.00	231.00	233.00	327.00	329.00	406.00
		407.00	409.00	415.00					
28-32	8	104.02	237.00	328.00	330.00	332.00	405.03		
32+	9	105.00	234.00	235.00	236.00	238.00	239.00	240.00	241.00
		242.00	243.00	331.00	333.00	334.00	335.00	336.00	401.00
		402.00	403.00	404.00	405.01	405.02			

Table 40: Mean Radiowave Band Density Estimates By Geographic Region, in nanowatts per cm^2

County Geographic Region	1970 Population	Mean Radiowave Density Estimates, in nanowatts per cm^2					
		Low VHF (54-88 MHz)		FM radio (88-108 MHz)		High VHF (176-216 MHz)	
		CT mean	BG range	CT mean	BG range	CT mean	BG range
Multnomah Co.	**555667**	**2.1**	**0.1-117.4**	**39.2**	**0.8-5889.1**	**4.9**	**0.2-289.3**
Northwest	4847	8.7	0.2-87.7	21.6	0.8-117.8	34.7	0.4-289.3
West Hills	22641	9.5	0.3-117.4	493.3	6.9-5889.1	18.4	1.3-121.3
Southwest	31622	3.4	0.7-28.2	87.3	11.0-702.8	8.2	2.0-87.1
Downtown	29346	3.7	0.4-23.1	34.7	5.1-357.3	6.7	0.8-78.6
Peninsula	53005	2.4	0.6-30.3	9.9	2.8-71.2	6.4	1.8-106.5
North Central	35583	2.4	0.5-21.2	13.9	4.8-88.0	5.9	1.5-39.8
Central	26852	2.4	0.6-11.0	39.7	6.5-149.1	5.8	1.9-22.8
South Central	61453	1.6	0.3-5.9	23.5	6.3-90.8	3.7	0.8-11.9
Southeast	65751	1.6	0.4-6.6	14.6	3.9-64.9	3.8	1.2-12.7
East Southeast	72438	1.1	0.1-6.5	13.8	1.0-82.3	2.2	0.3-8.5
Northeast	56321	1.8	0.4-6.6	11.2	3.2-34.0	4.3	1.1-12.8
East Northeast	59655	1.3	0.3-6.8	6.7	1.8-21.9	2.6	0.7-11.2
East	37153	0.9	0.1-5.6	3.5	0.6-10.2	1.5	0.2-6.0
Clackamas Co.	**166088**						
Northwest	35332	1.3	0.5-3.9	25.8	8.0-66.7	3	1.2-8.1
North Central	65954	1.2	0.2-5.7	35.1	4.1-293.1	2.5	0.6-10.0
Central	20591						
East	23855						
Southwest	20356						
Washington Co.	**157920**						
Northeast	81172	4.5	0.4-38.2	17	2.6-138.0	12.5	1.5-171.4
Southeast	29743	1.6	0.4-8.4	15.7	5.1-90.7	4	1.1-17.8
Central	39586						
Northwest	7419						
Clark Co.	**128454**						
West Vancouver	22659	1.3	0.2-9.2	4	1.1-18.4	2.5	0.6-14.5
East Vancouver	25728	1.3	0.2-9.2	4.5	1.1-20.1	2.5	0.5-14.5
Northeast Suburb	22668	1.2	0.2-8.5	4	0.9-15.9	2.2	0.4-11.6
Southeast	21831	1	0.2-6.6	2.8	0.8-12.9	1.4	0.3-8.1
North	35568						

CT: Census tract
BG: Block group
BG range: regional limits of $\pm$ 1 standard deviation of BG values for that census tract

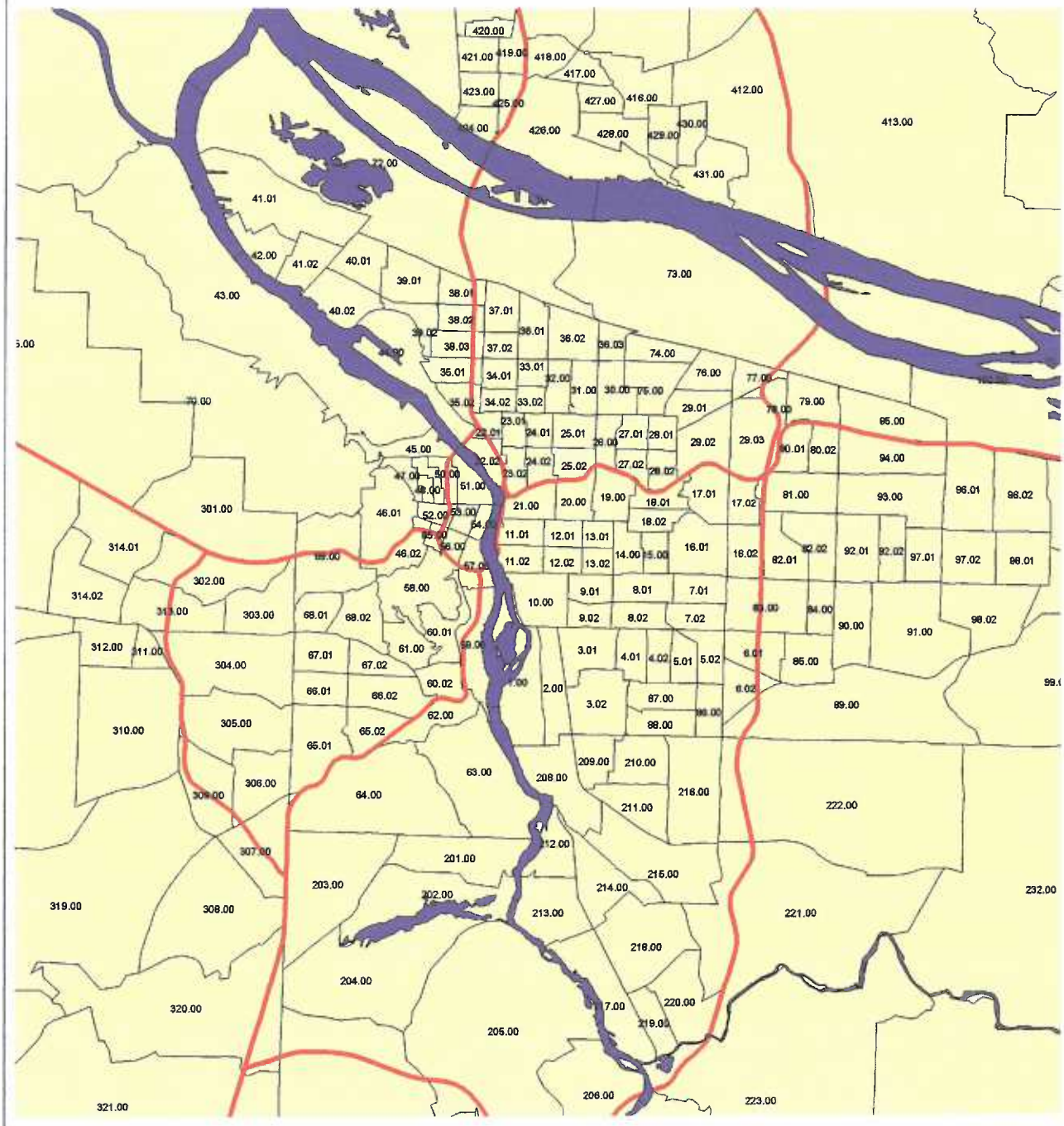
Table 41: Mean Radiowave Band Density Estimates for N2 Zones, in nanowatts per cm^2

Distance (km)	Zone	Mean Radiowave Density Estimates, in nanowatts per cm^2		
		Low VHF (54-88 MHz)	FM radio (88-108 MHz)	High VHF (176-216 MHz)
0-4	1	10.283	61.024	23.010
4-8	2	3.484	81.226	14.916
8-12	3	2.226	16.101	4.425
12-16	4	1.256	14.142	2.771
16-20	5	0.955	17.139	1.863
20-24	6	0.690	5.507	1.122
24-28	7	0.512	2.433	0.799
28-32	8	0.424	1.301	0.552
32+	9	0.038	0.118	0.052

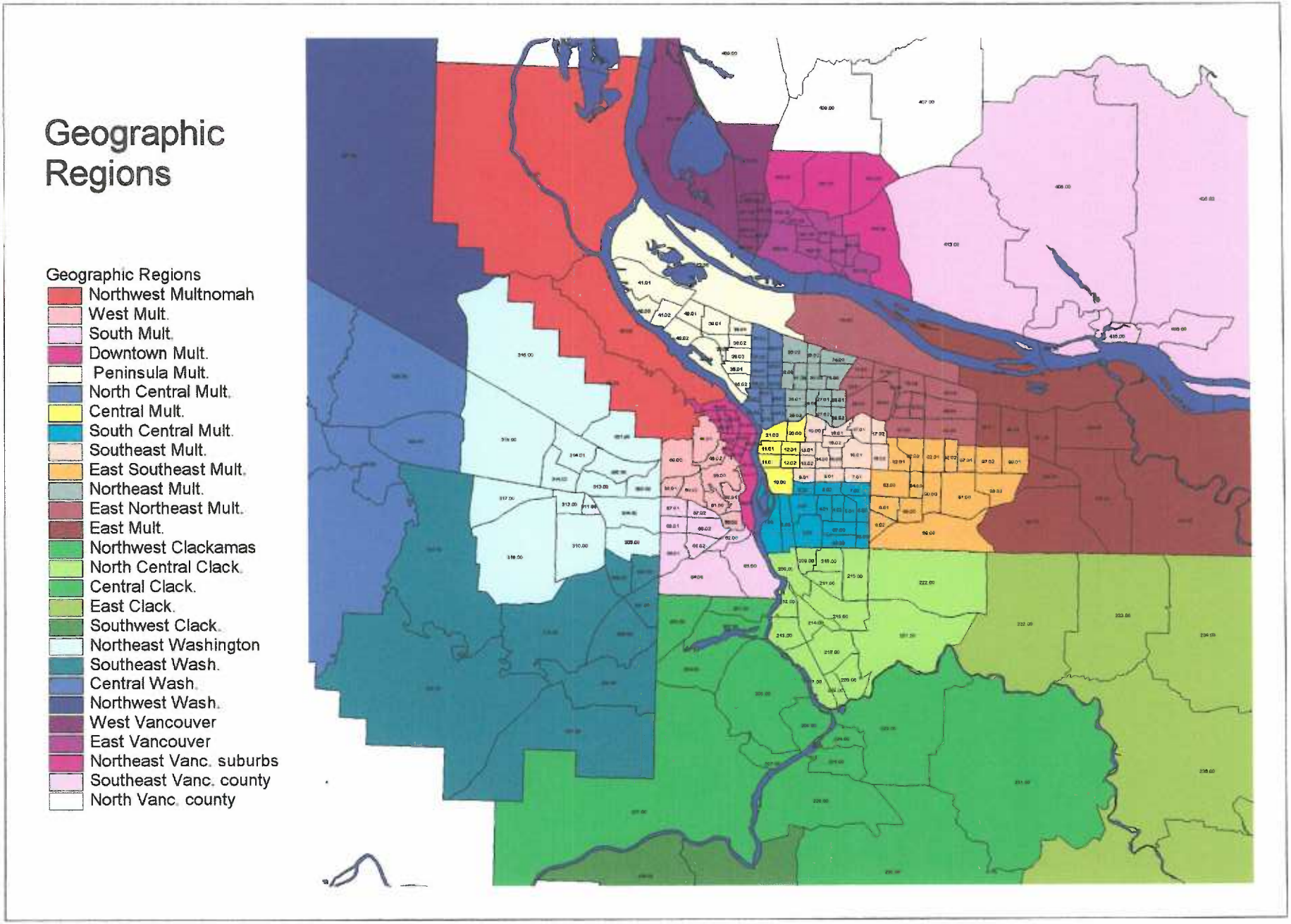
Table 42: Mean Radiowave Band Density Estimates for S1 Zones, in nanowatts per cm^2

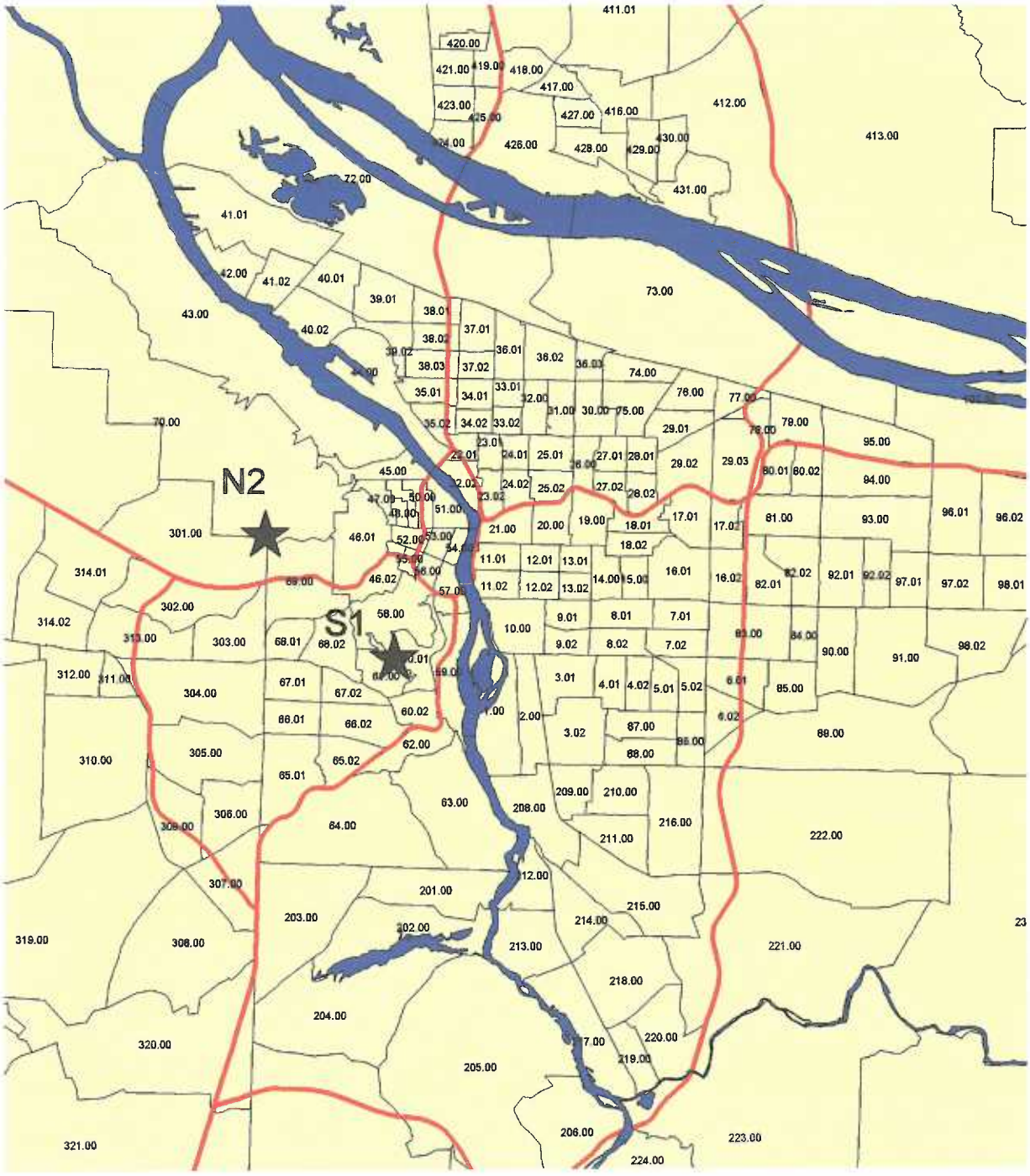
Distance (km)	Zone	Mean Radiowave Density Estimates, in nanowatts per cm^2		
		Low VHF (54-88 MHz)	FM radio (88-108 MHz)	High VHF (176-216 MHz)
0-4	1	5.601	238.033	12.012
4-8	2	3.217	21.826	7.013
8-12	3	1.925	14.676	8.918
12-16	4	1.229	17.427	2.716
16-20	5	0.827	5.145	1.542
20-24	6	0.743	2.685	1.191
24-28	7	0.412	1.369	0.573
28-32	8	0.114	0.356	0.156
32+	9	0.141	0.259	0.165

Maps


420.00
421.00
419.00
418.00
417.00
423.00
427.00
416.00
412.00
413.00
426.00
428.00
429.00
430.00
431.00
41.01
42.00
41.02
40.01
39.01
73.00
43.00
40.02
38.01
37.01
38.02
36.01
36.02
36.03
74.00
38.03
37.02
35.01
34.01
33.01
76.00
77.00
34.02
33.02
31.00
30.00
29.01
79.00
95.00
24.01
25.01
27.01
28.01
29.02
29.03
80.02
94.00
45.00
25.02
27.02
301.00
46.01
21.00
20.00
19.00
18.01
17.01
17.02
81.00
93.00
96.01
96.02
18.02
314.01
11.01
12.01
13.01
14.00
16.01
16.02
82.01
92.01
97.01
97.02
98.01
46.02
11.02
12.02
13.02
302.00
314.02
58.00
9.01
8.01
7.01
10.00
9.02
8.02
7.02
84.00
90.00
91.00
98.02
303.00
68.01
68.02
60.01
312.00
311.00
304.00
67.01
67.02
61.00
3.01
4.01
5.01
5.02
85.00
66.01
68.02
60.02
2.00
3.02
87.00
89.00
310.00
305.00
62.00
65.02
65.01
88.00
209.00
210.00
63.00
208.00
306.00
64.00
218.00
222.00
211.00
307.00
212.00
201.00
203.00
215.00
214.00
319.00
308.00
202.00
213.00
221.00
232.00
218.00
204.00
320.00
220.00
205.00
219.00
206.00
223.00
321.00
N
W
E
S
1970 Census Tracts
Portland - Vancouver
Metropolitan Area

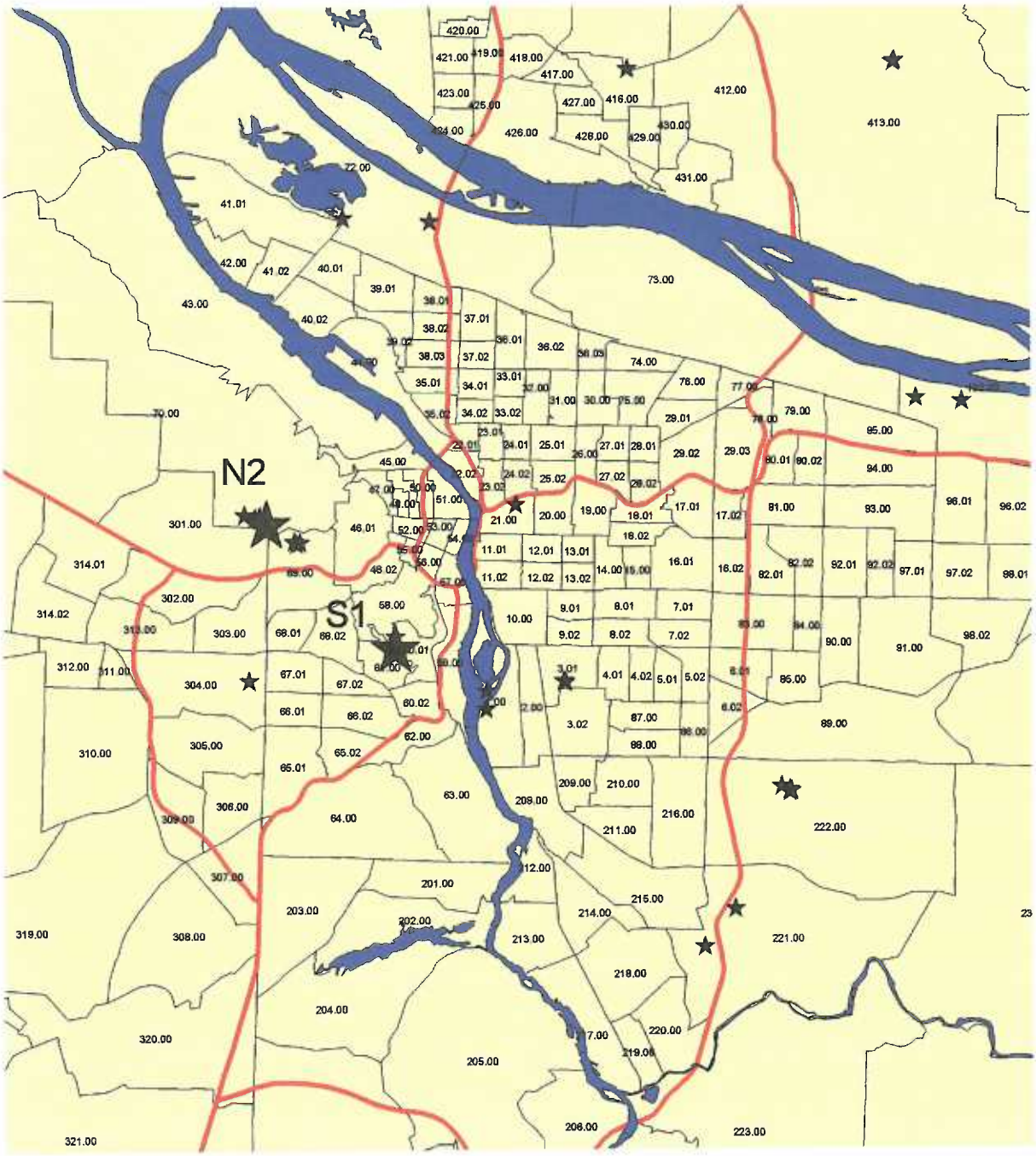
Geographic Regions



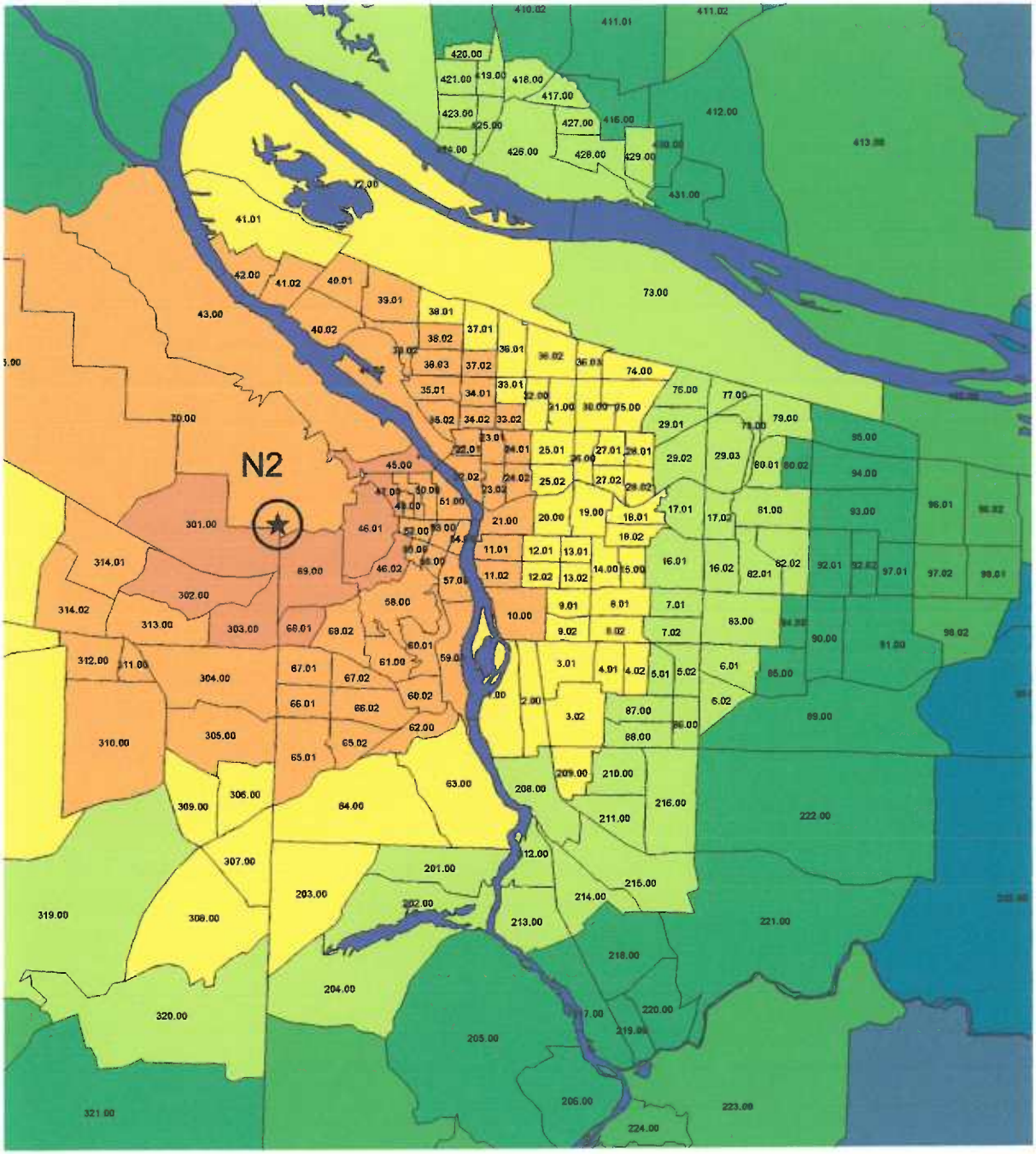


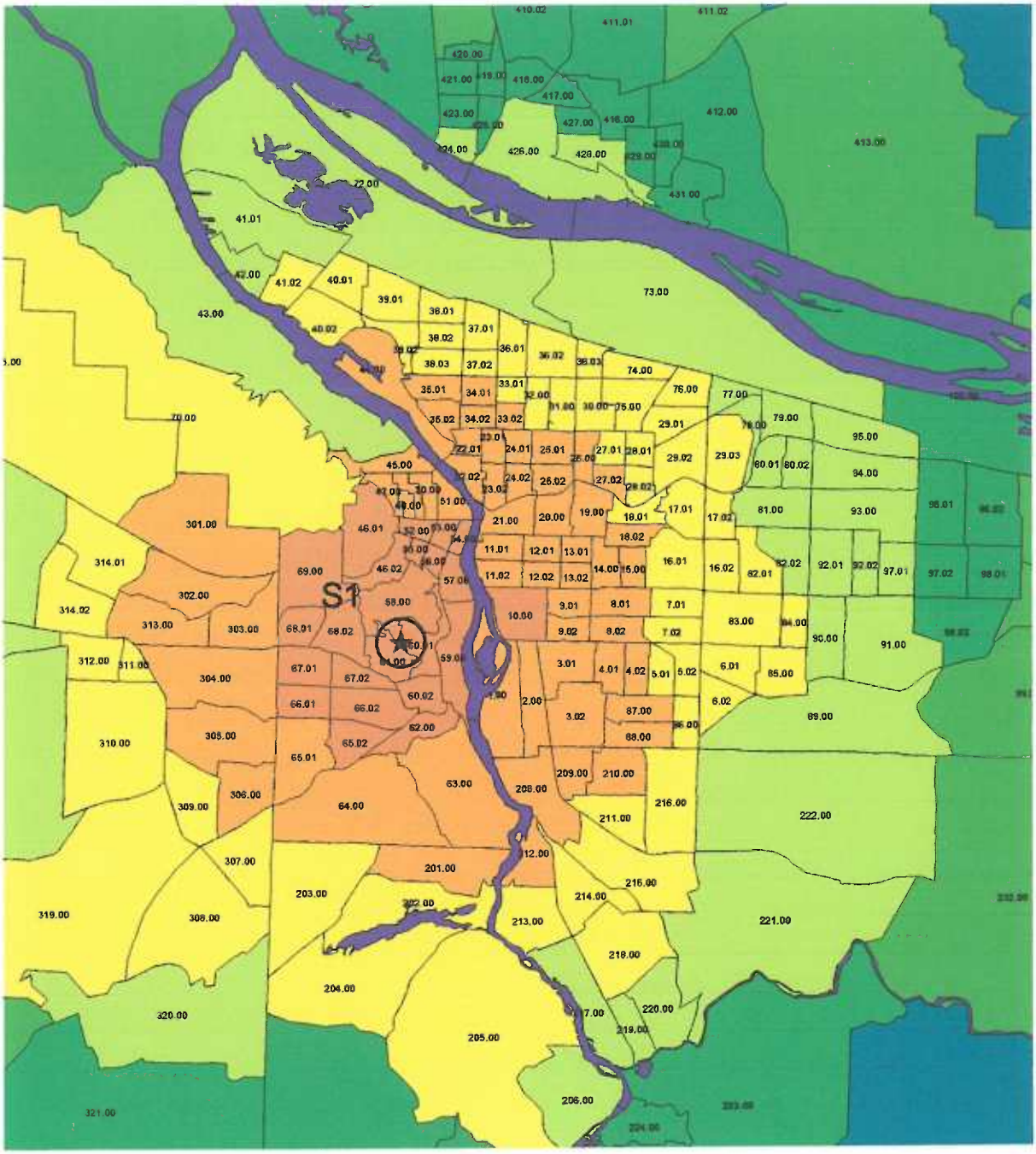
N
W E
S

Broadcast Tower Locations
N2 and S1 Towers

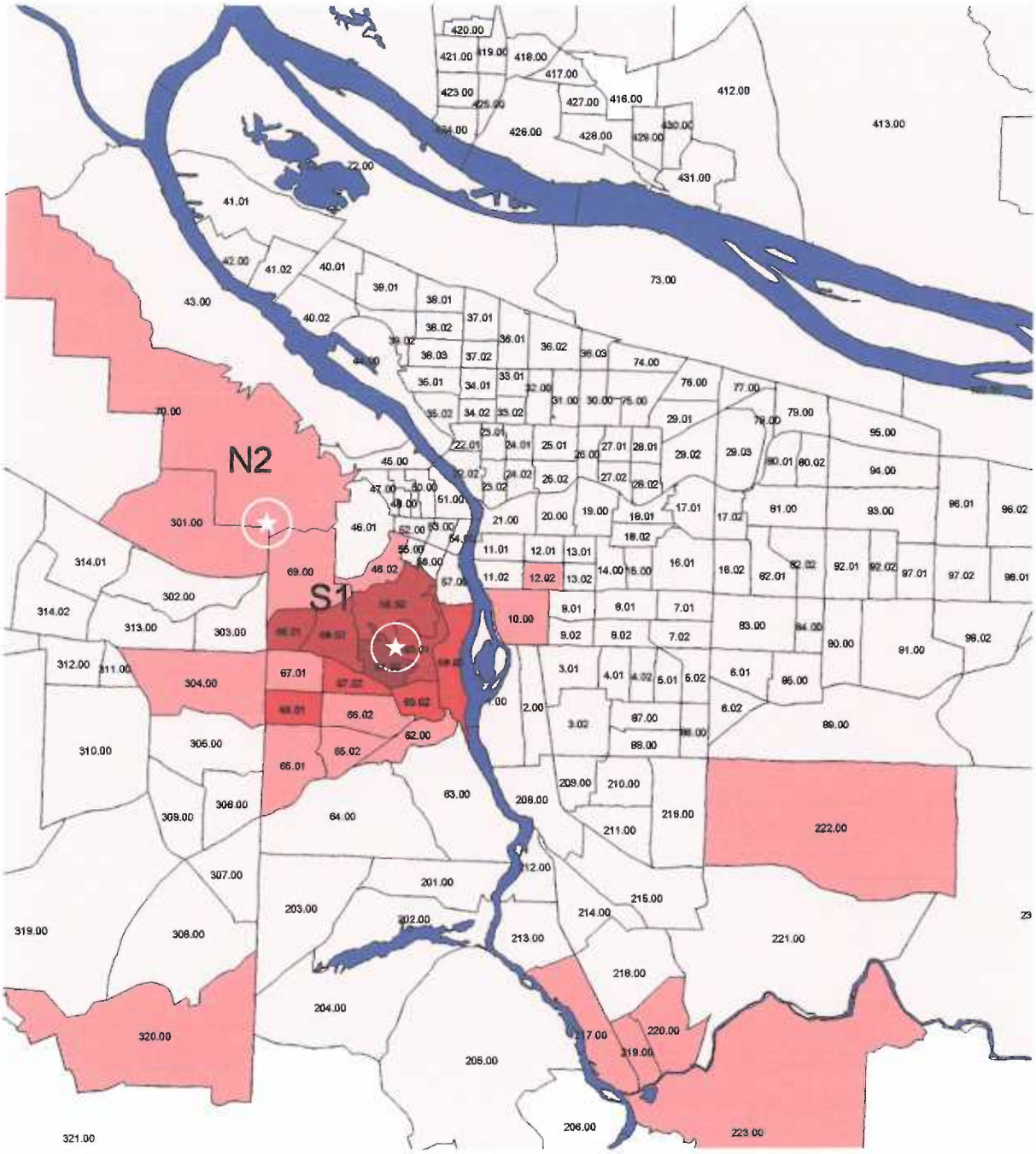


Broadcast Tower Locations
All Tower Sites


N2
Distance Zones
1
2
3
4
5
6
7
8
9
Distance Zones Around
N2 Tower



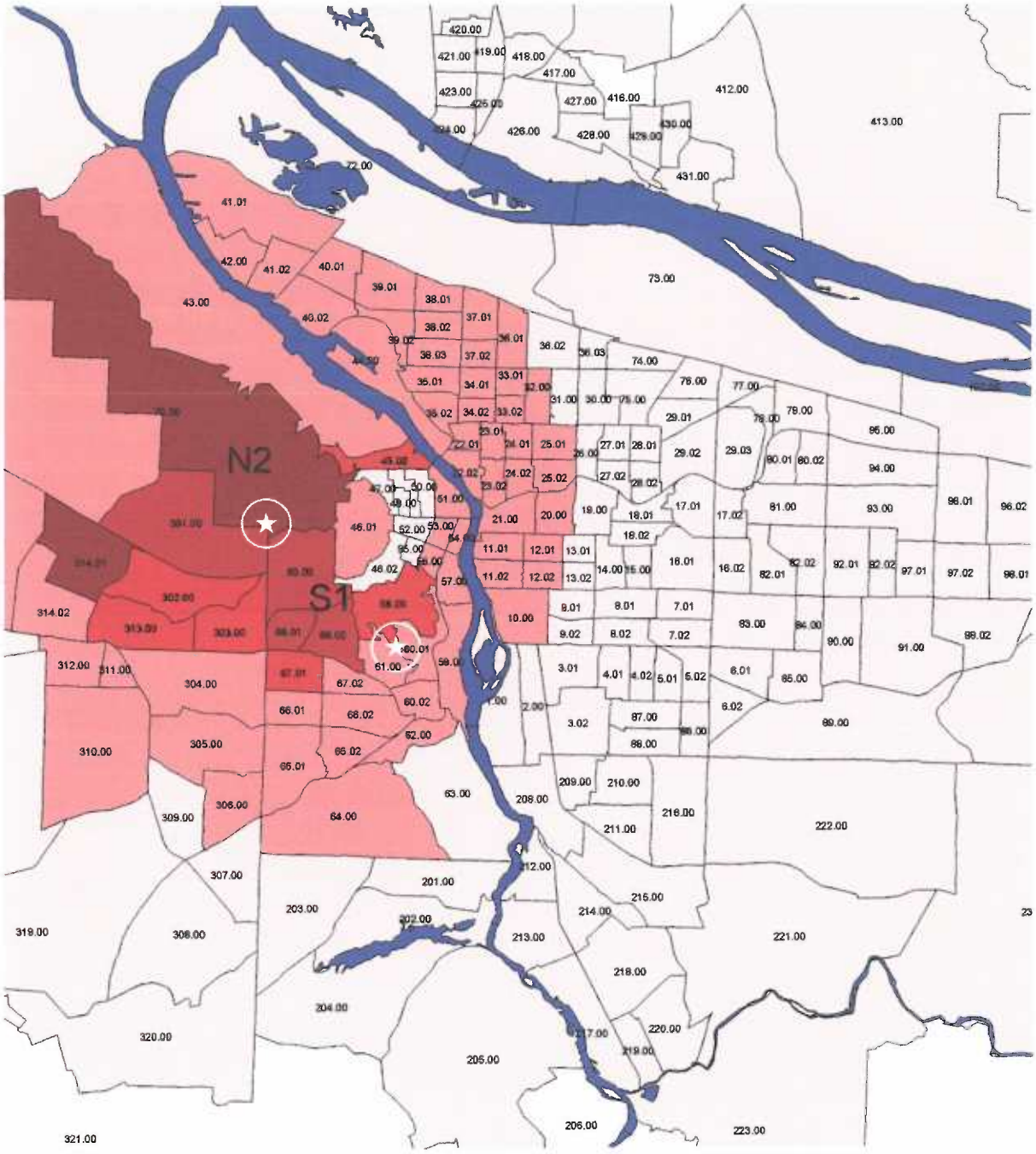
Distance Zones Around S1 Tower



Mean Radiowave Density, in nanowatts/cm2

- 2.2 - 37.4
- 37.4 - 111.3
- 111.3 - 292
- 292 - 732.8
- 732.8 - 1757.9

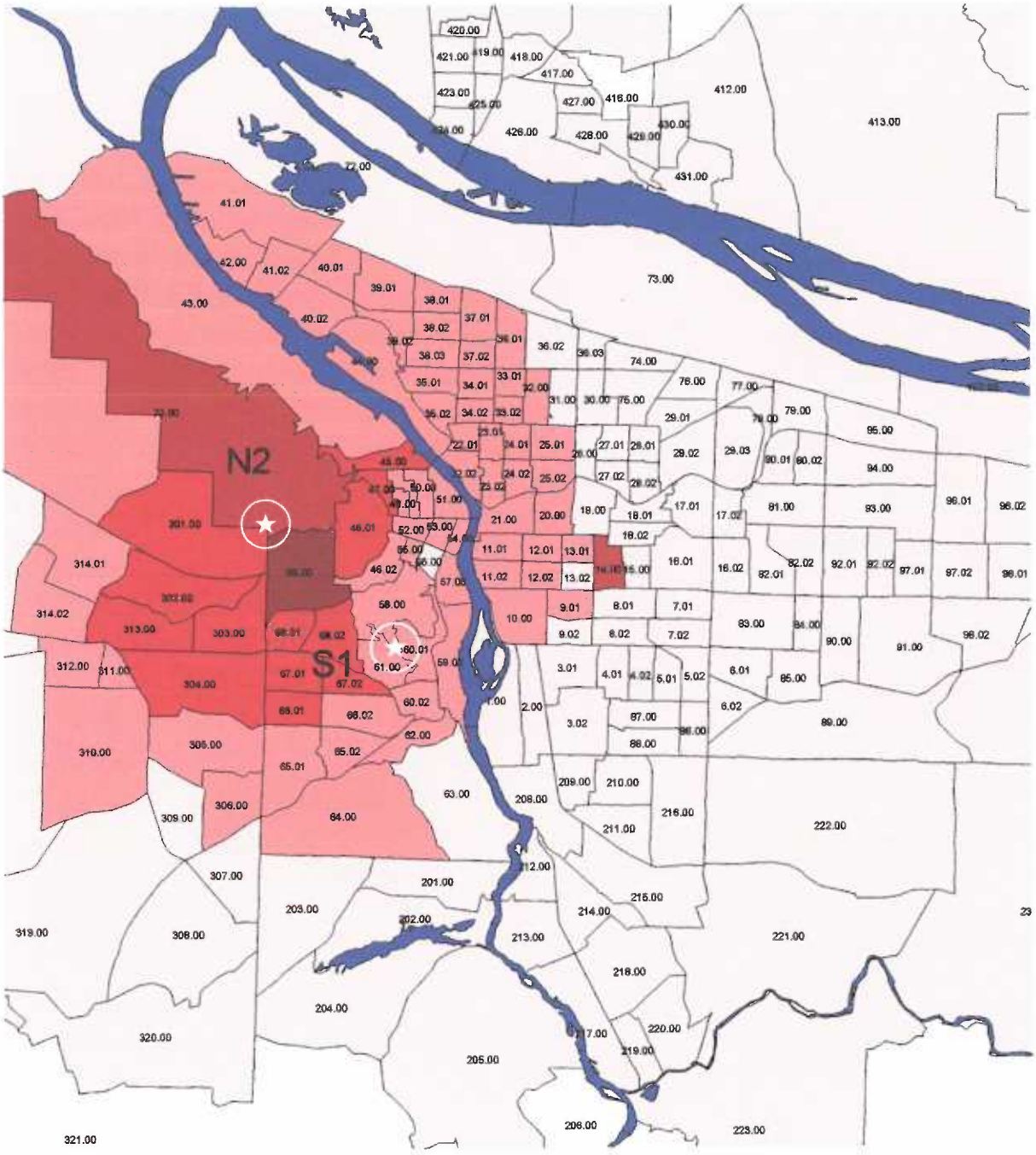
FM Band Density by Census Tract

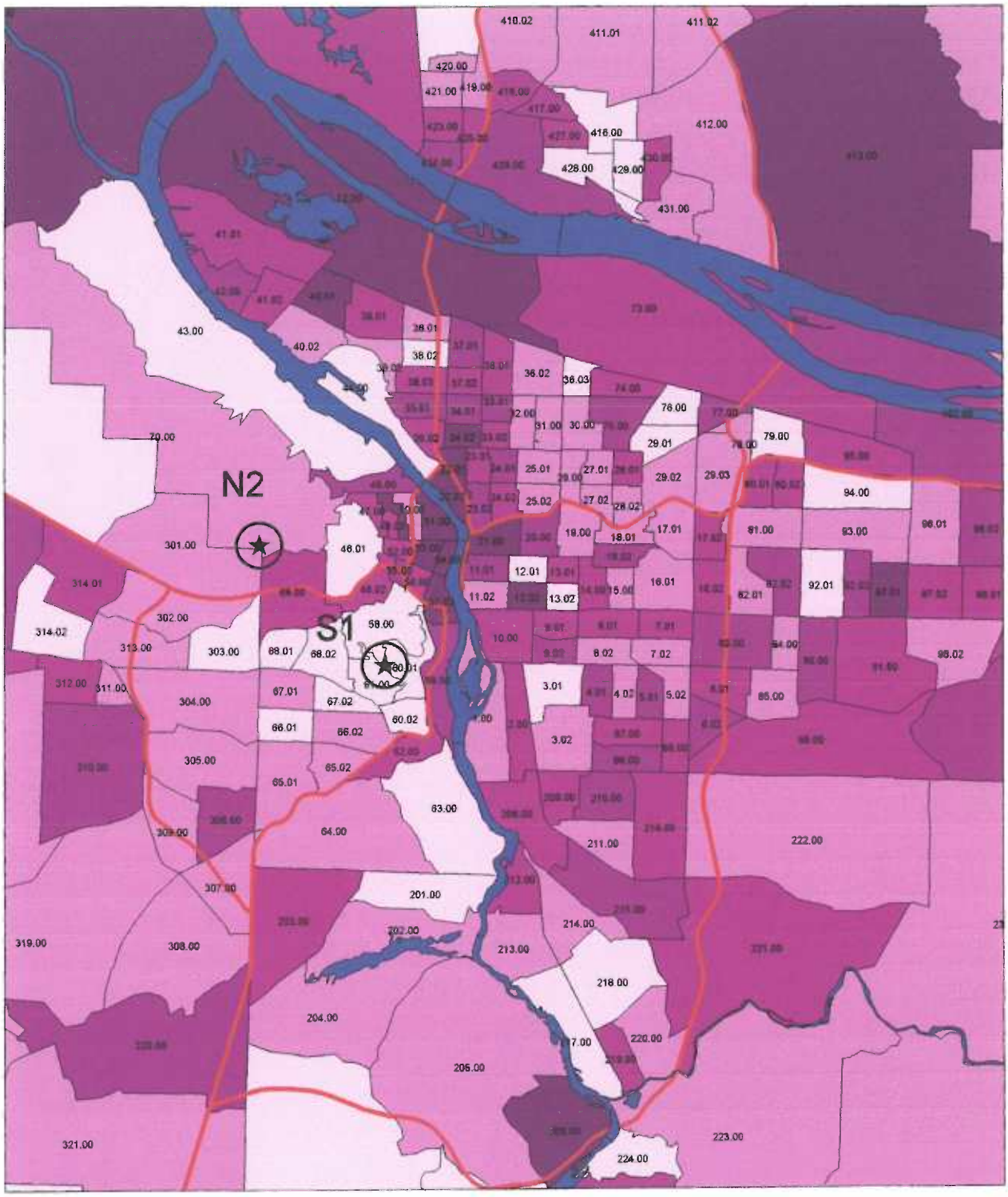


Mean Radiowave Density, in nanowatts/cm2

- 1.1 - 4.8
- 4.8 - 12.6
- 12.6 - 27
- 27 - 52.4
- 52.4 - 118

High VHF Band Density by Census Tract

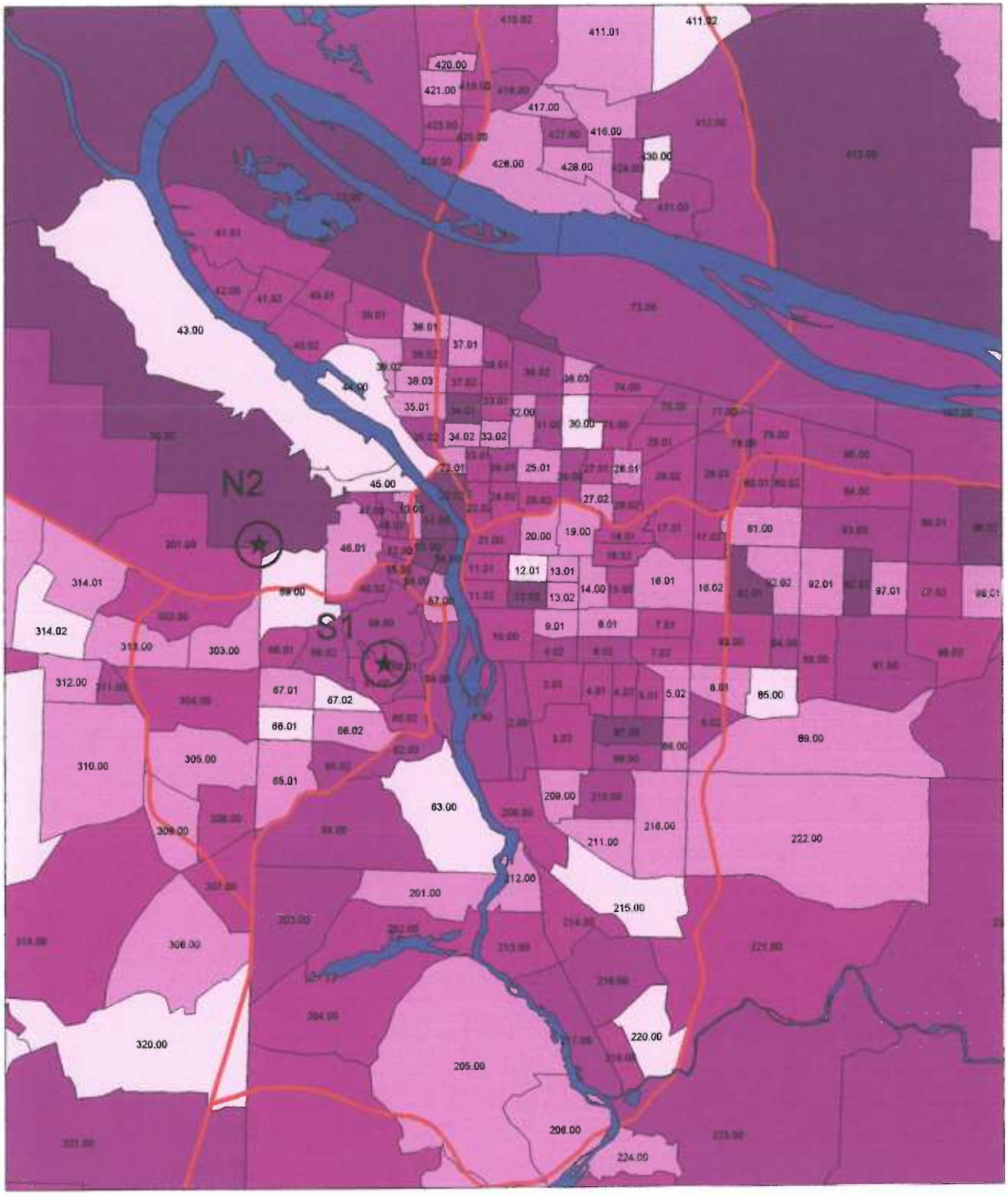

N2
S1
Mean Radiowave Density, in nanowatts/cm2
0.7 - 1.9
1.9 - 4.8
4.8 - 10.3
10.3 - 19.5
19.5 - 44.4
Low VHF Band Density
by Census Tracts



Standardized Incidence Ratio

- 0 - 66
- 66 - 96
- 96 - 124
- 124 - 160
- 160 - 220

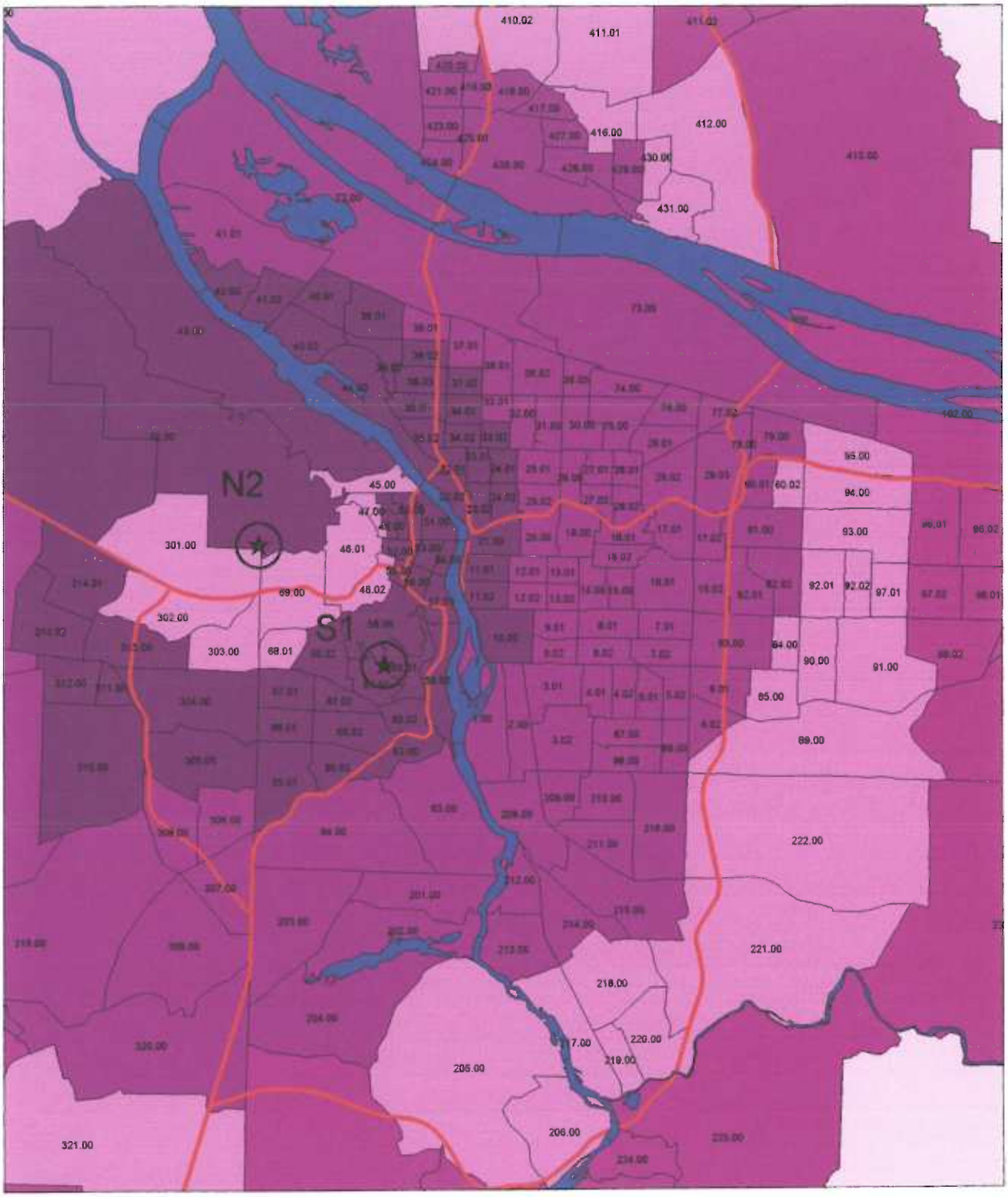
Total Lung Cancer in Males
by Census Tract



Standardized Incidence Ratio

- 0 - 40
- 40 - 80
- 80 - 123
- 123 - 190
- 190 - 436

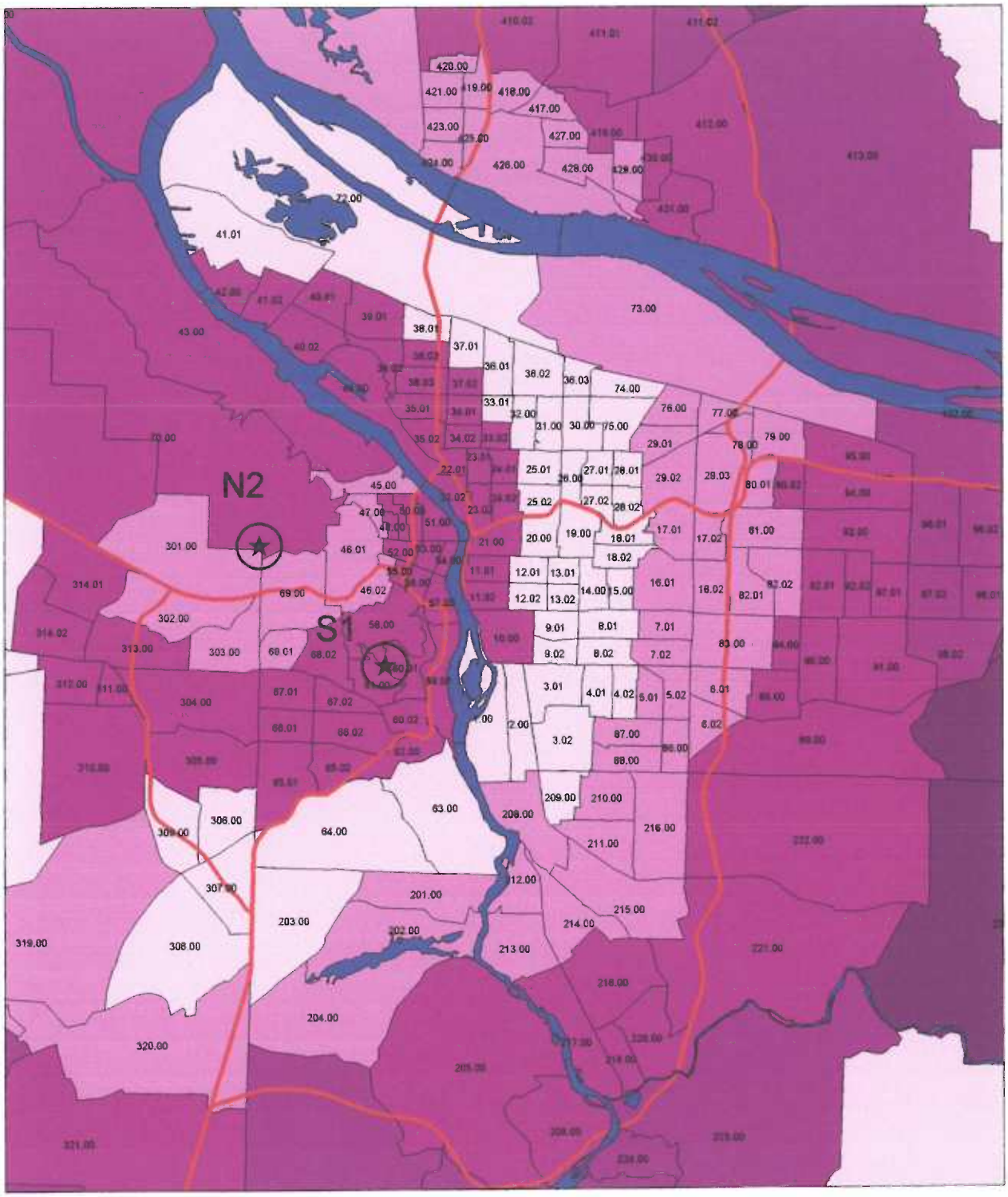
Total Lung Cancer in Females
by Census Tract



Standardized Incidence Ratio

- 84
- 84 - 90
- 90 - 97
- 97 - 100
- 100 - 115

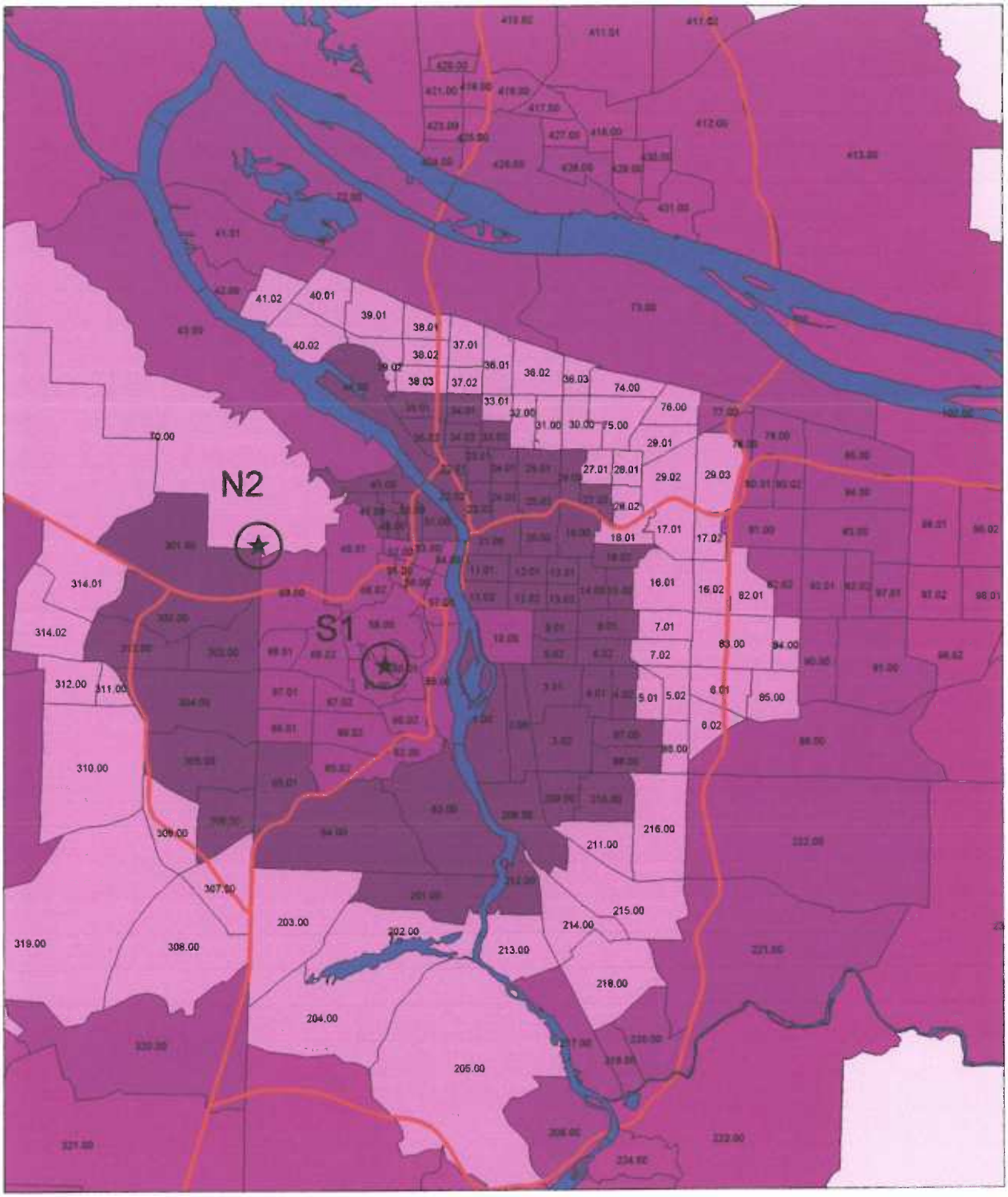
Total Lung Cancer in Males by N2 Distance Zones



Standardized Incidence Ratio

- 91 - 92
- 92 - 98
- 98 - 106
- 106 - 111
- 111 - 115

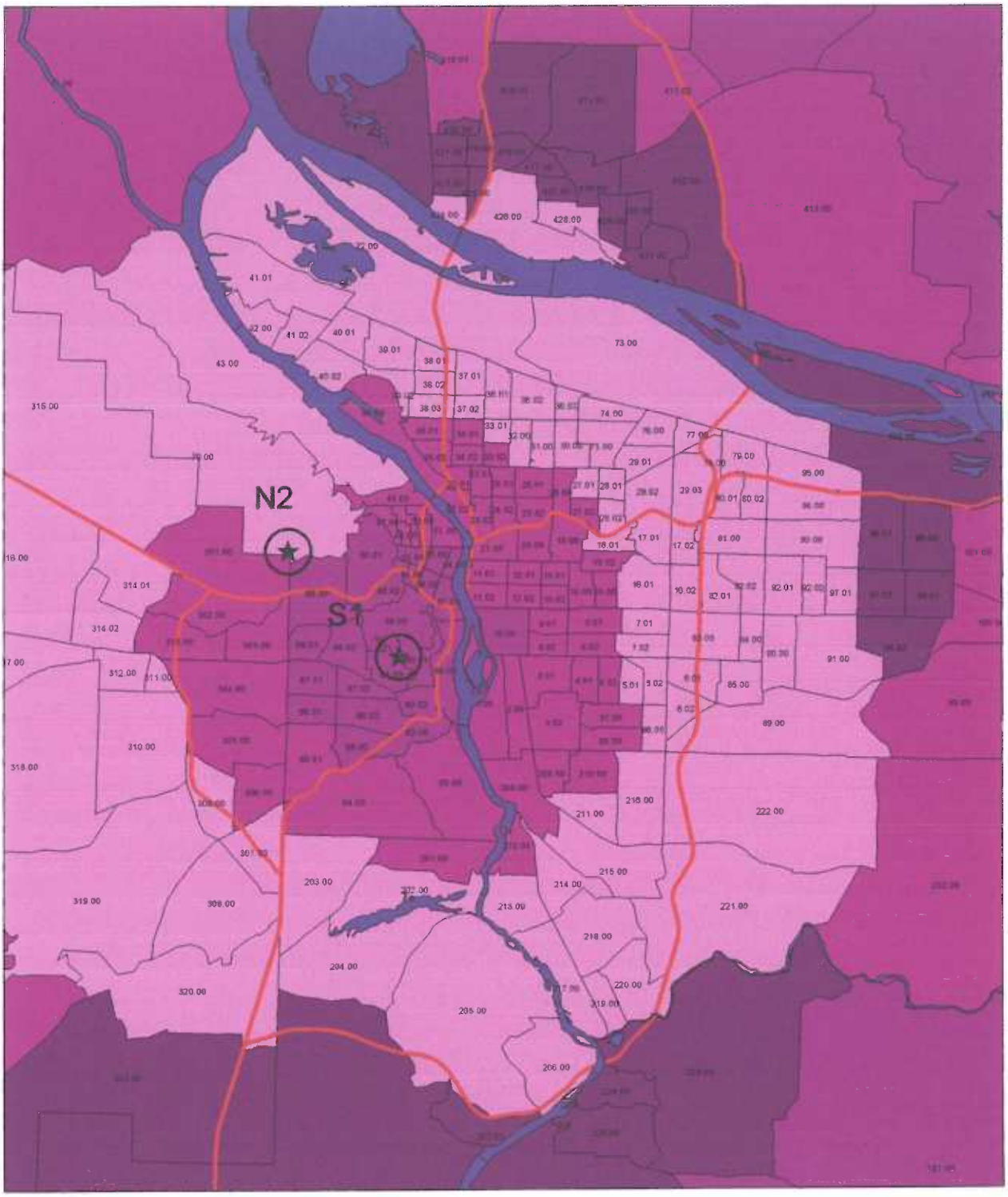
Total Lung Cancer in Females
by N2 Distance Zones



Standardized Incidence Ratio

- 72 - 73
- 73 - 91
- 91 - 93
- 93 - 107
- 107 - 113

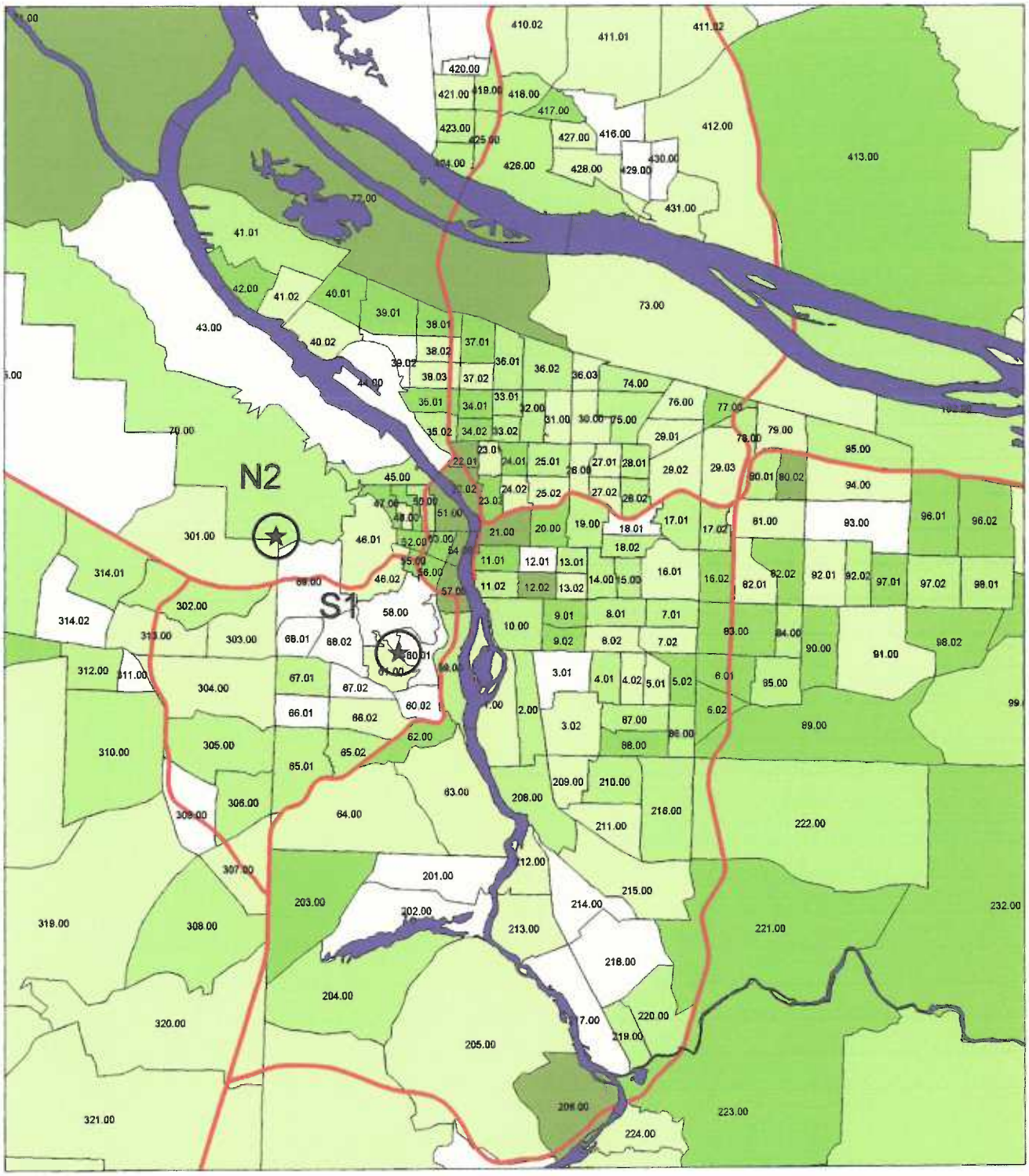
Total Lung Cancer in Males
by S1 Distance Zones



Standardized Incidence Ratio

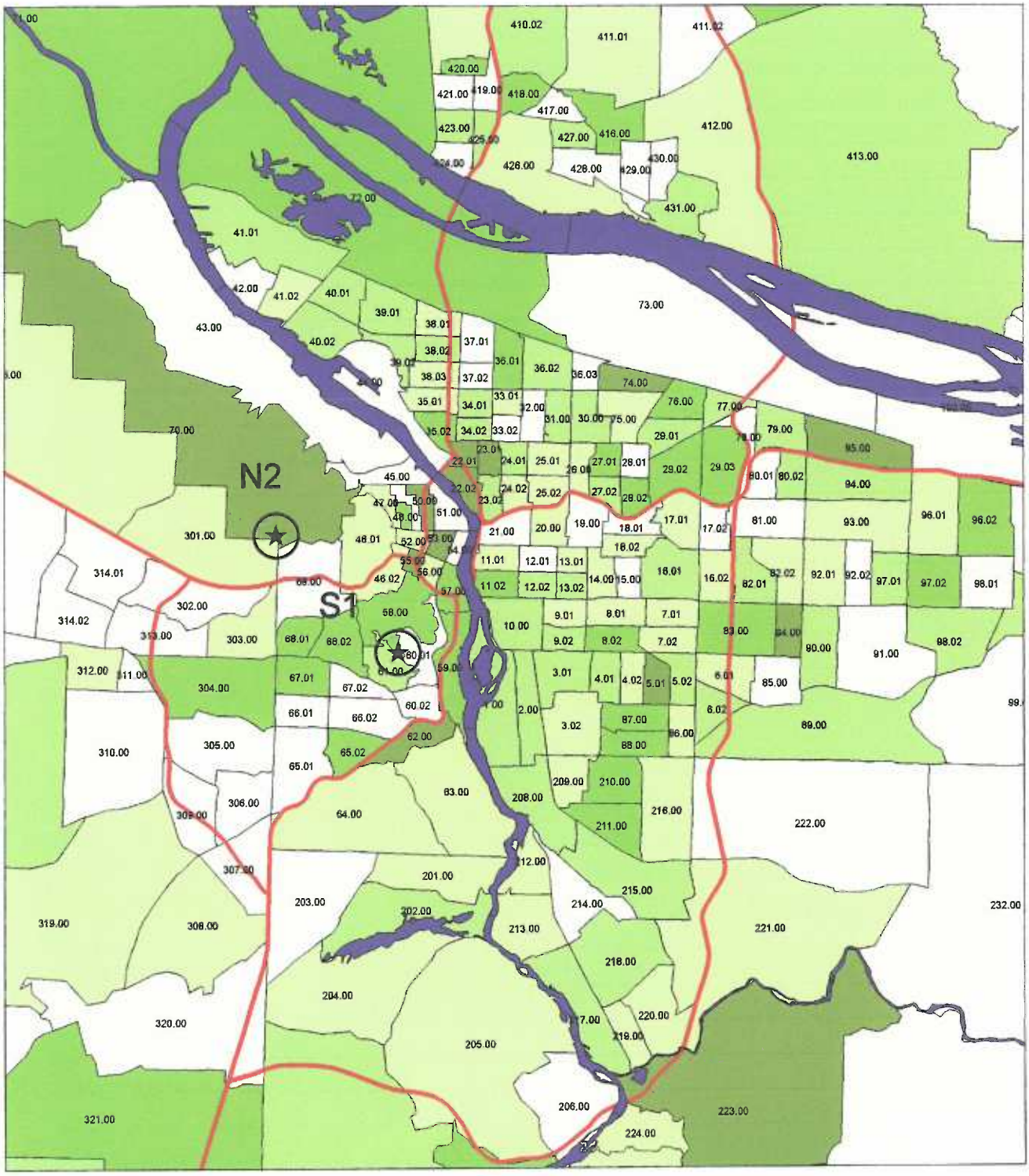
- 80
- 80 - 96
- 96 - 100
- 100 - 107
- 107 - 115

Total Lung Cancer in Females
by S1 Distance zones



Standardized Incidence Ratio
- 0 - 48
- 49 - 90
- 91 - 131
- 132 - 199
- 200 - 309

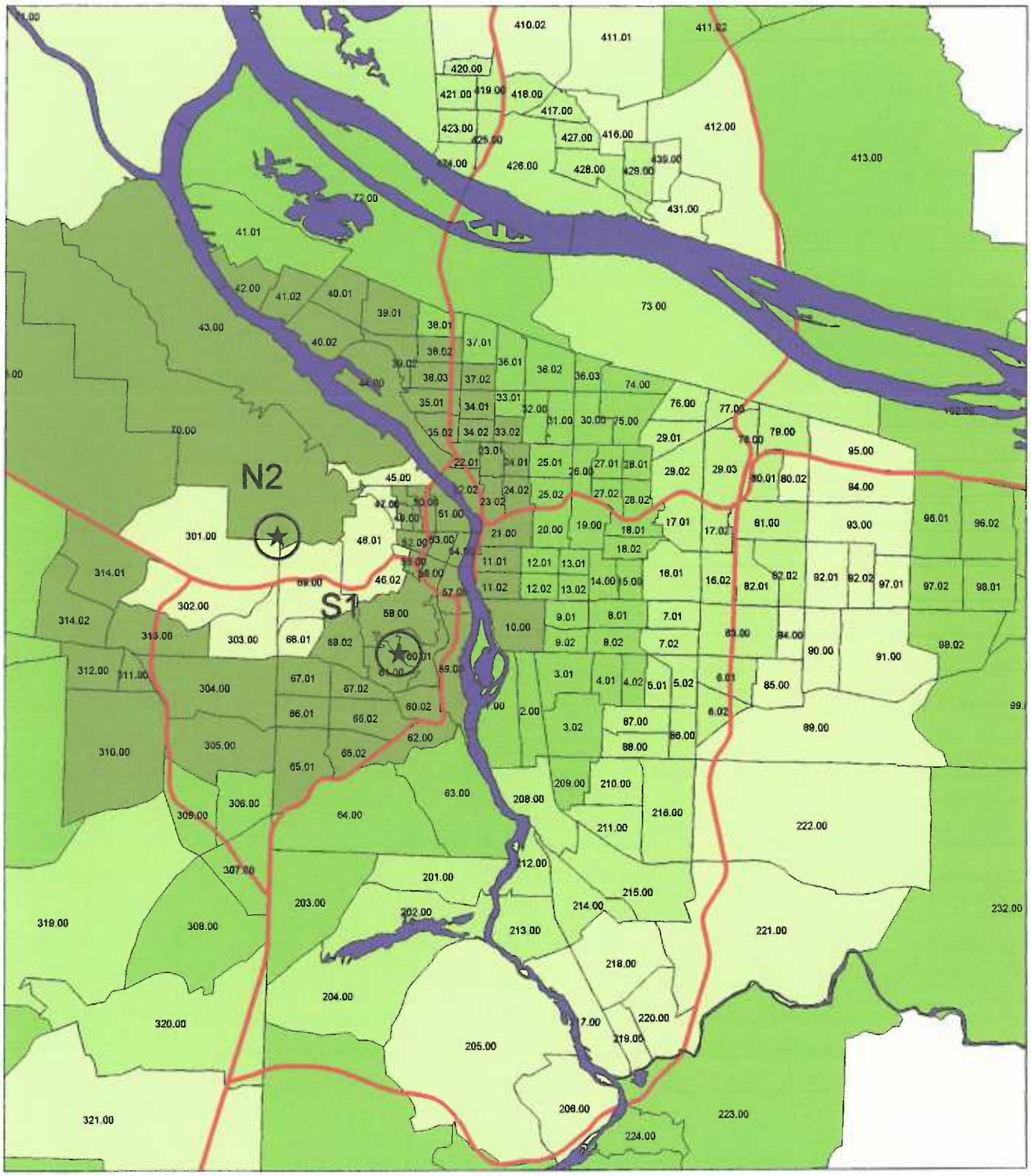
Squamous Cell Lung Cancer in Males by Census Tract



Standardized Incidence Ratio

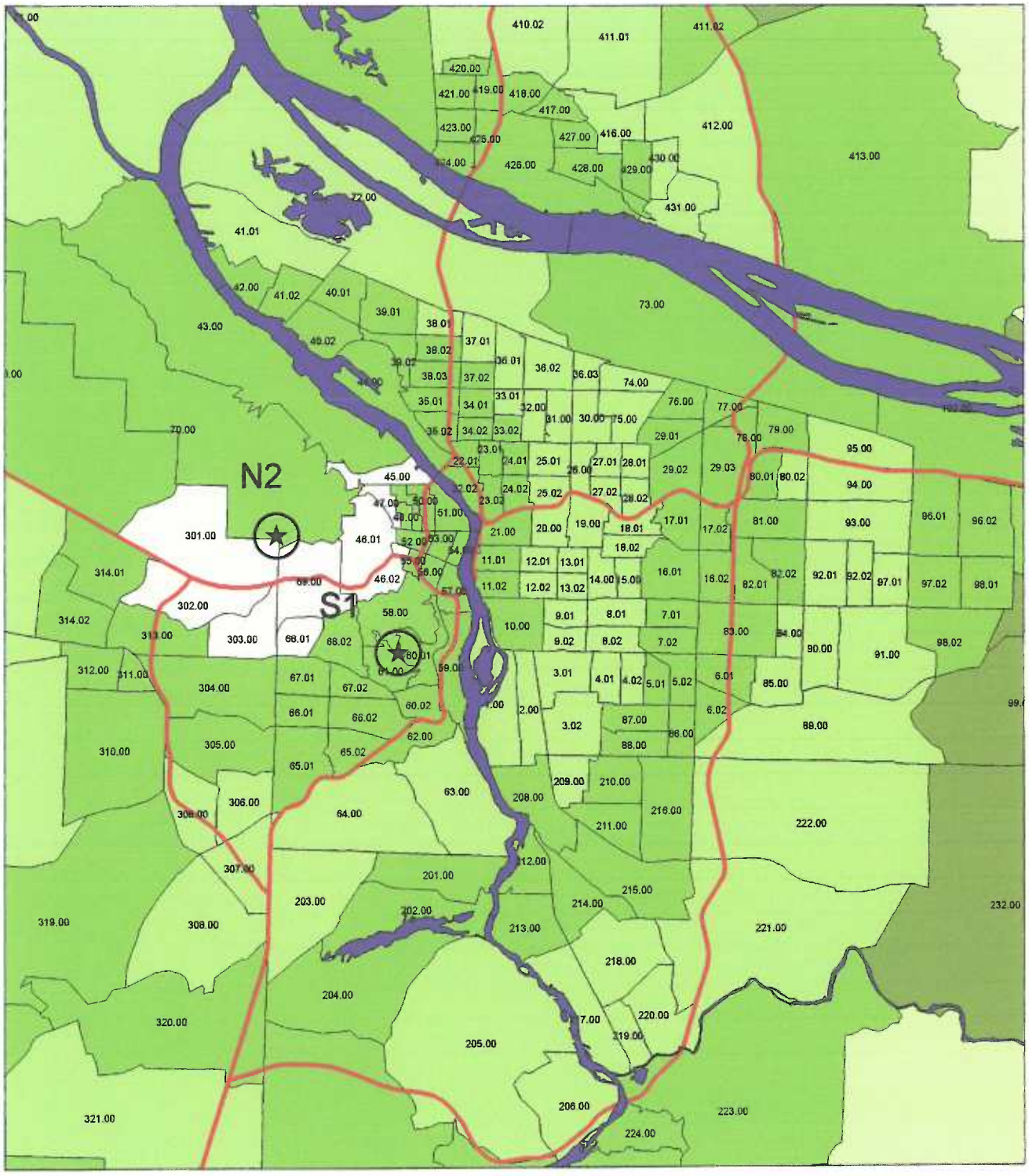
- 0
- 1 - 107
- 108 - 174
- 175 - 280
- 281 - 572

Squamous Cell Lung Cancer in Females by Census Tract



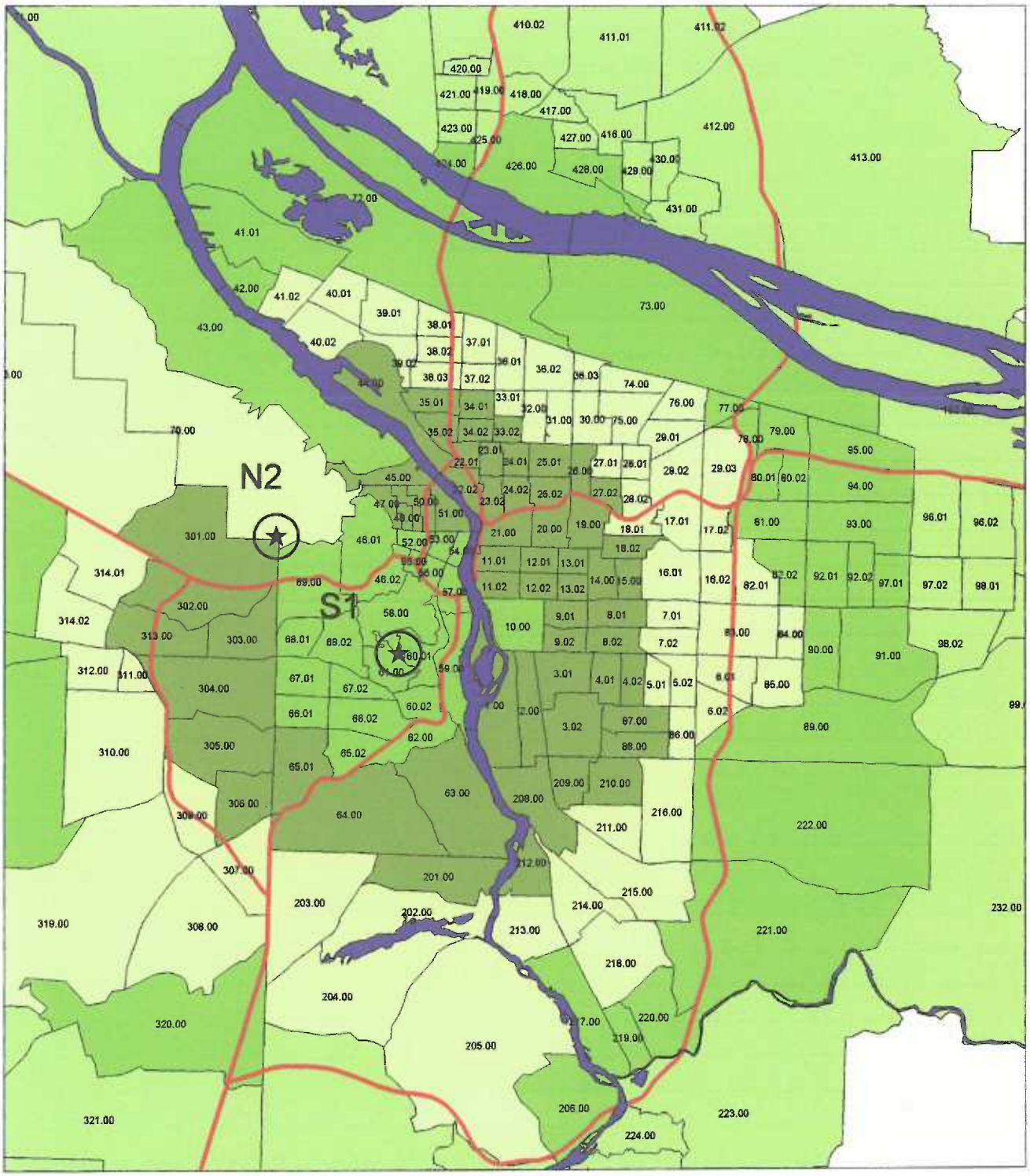
Standardized Incidence Ratio
- 85
- 85 - 87
- 87 - 95
- 95 - 102
- 102 - 119

Squamous Cell Lung Cancer in Males by N2 Distance Zone



Standardized Incidence Ratio
- 53
- 53 - 90
- 90 - 94
- 94 - 114
- 114 - 125

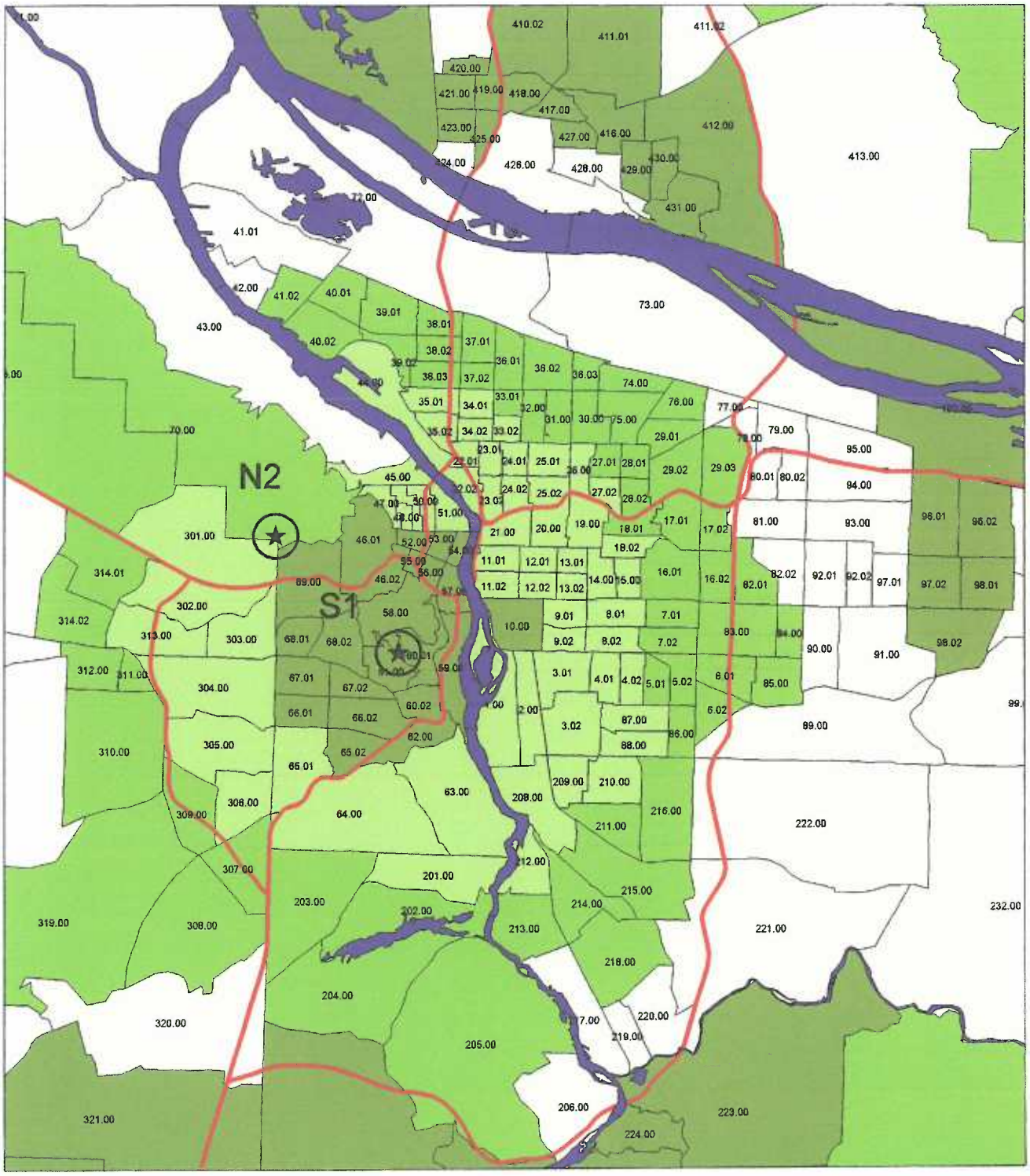
Squamous Cell Lung Cancer in Females by N2 Distance Zone



Standardized Incidence Ratio

- 72 - 73
- 73 - 91
- 91 - 93
- 93 - 107
- 107 - 113

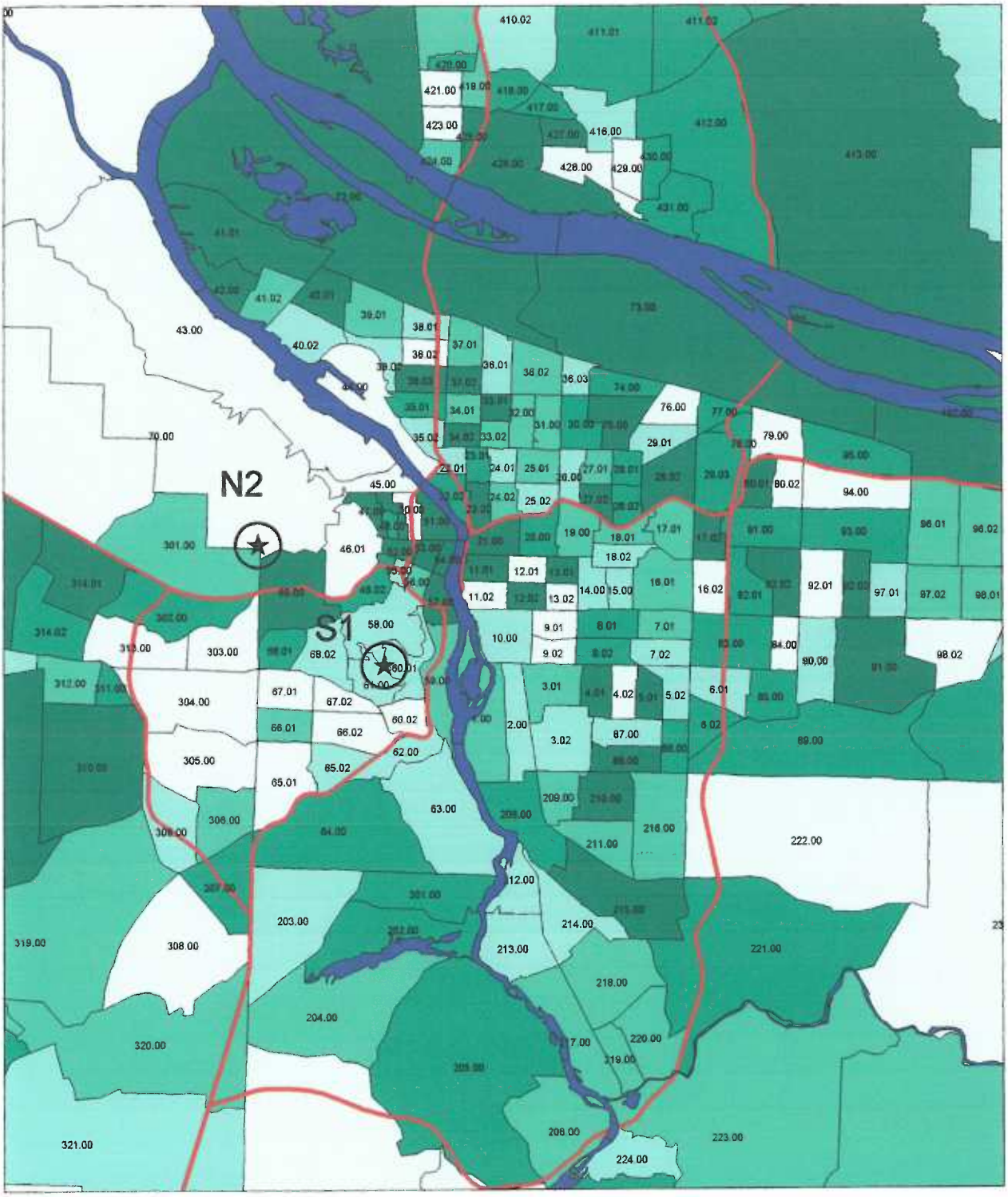
Squamous Cell Lung Cancer in Males by S1 Distance Zone



Standardized Incidence Ratio

- 73 - 80
- 80 - 89
- 89 - 97
- 97 - 106
- 106 - 130

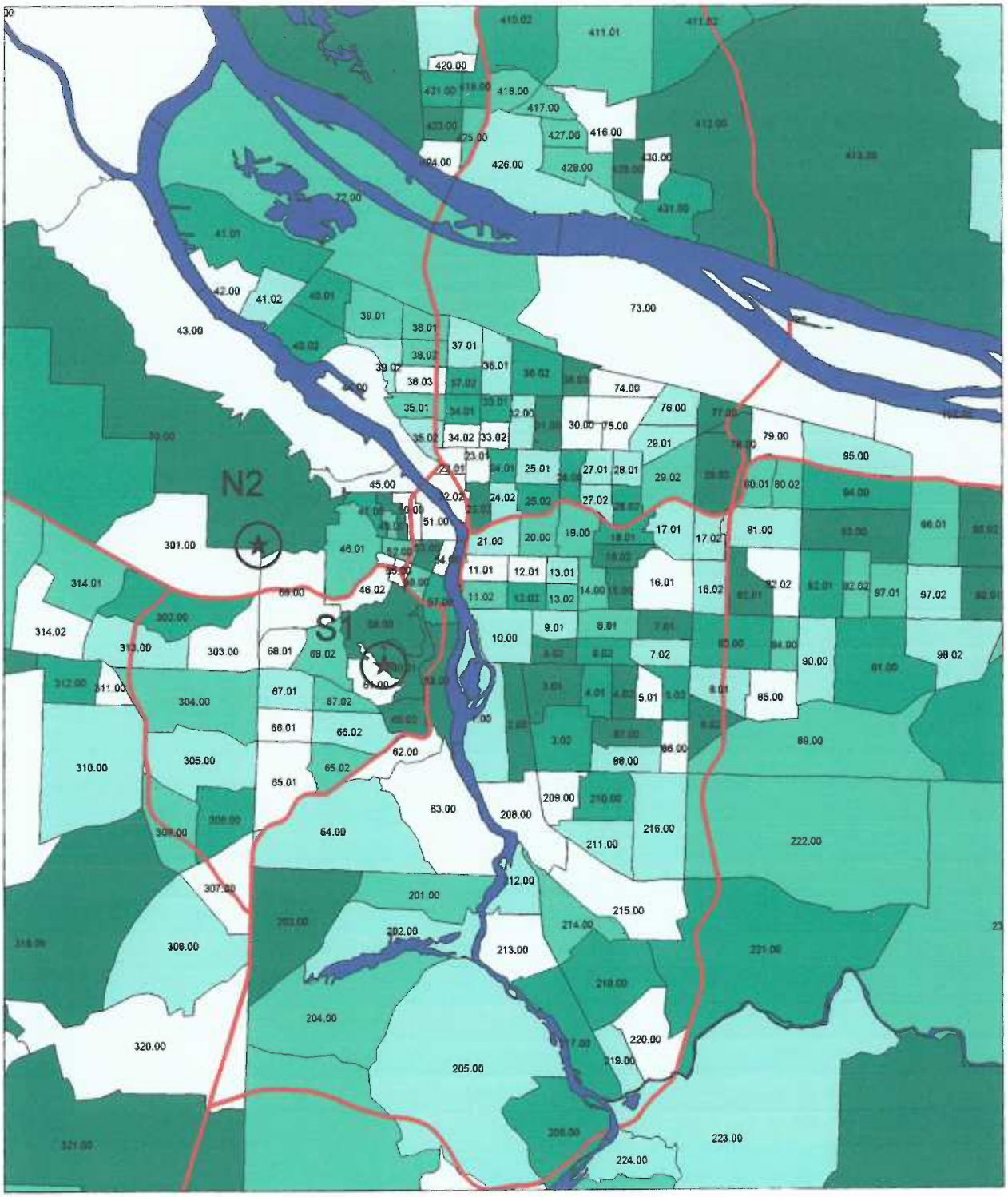
Squamous Cell Lung Cancer in Females by S1 Distance Zone



Standardized Incidence Ratio

- 0 - 53
- 54 - 78
- 79 - 106
- 108 - 146
- 147 - 334

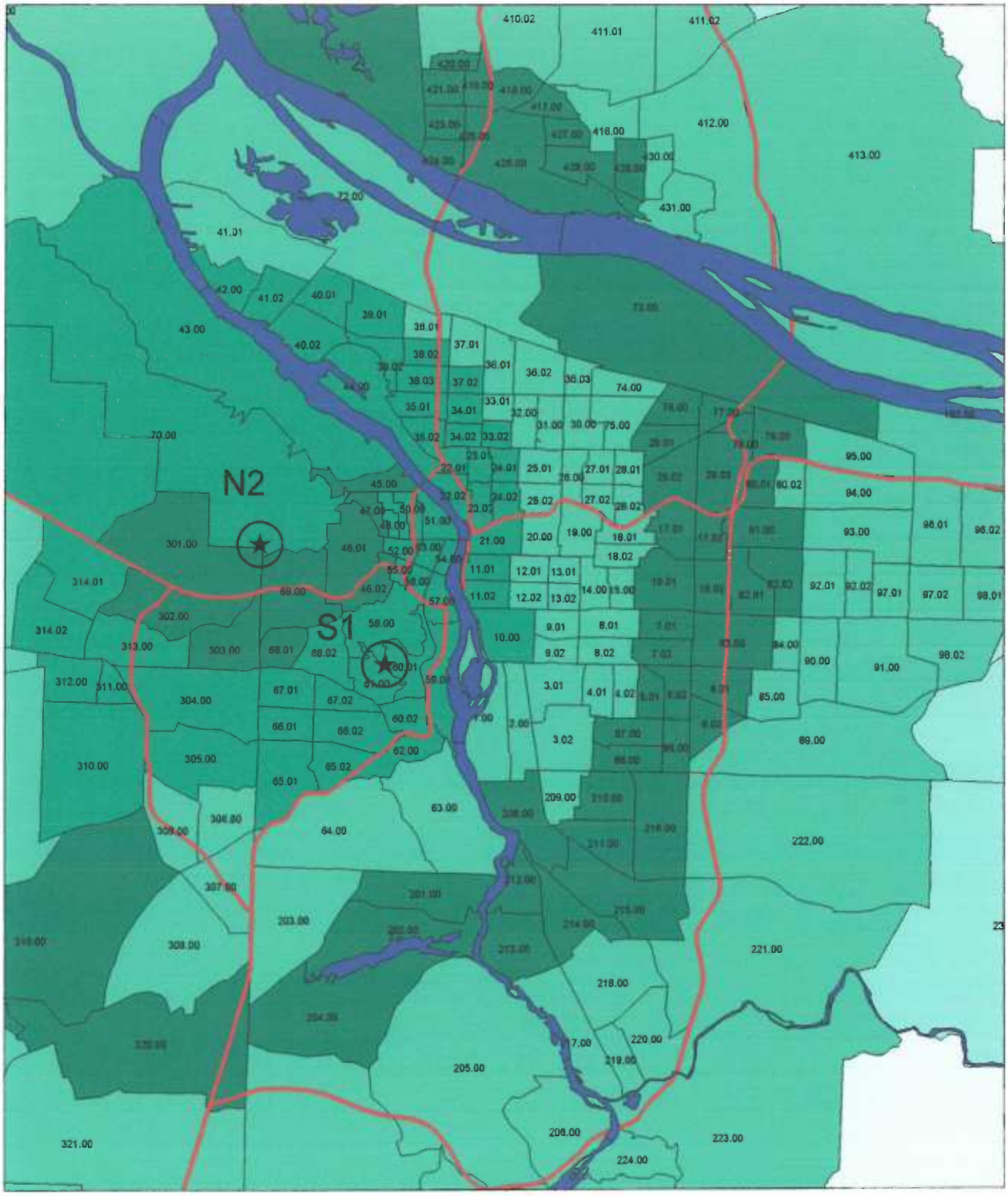
Lung Adenocarcinoma in Males
by Census Tract



Standardized Incidence Ratio

- 0
- 30 - 72
- 73 - 114
- 117 - 164
- 165 - 619

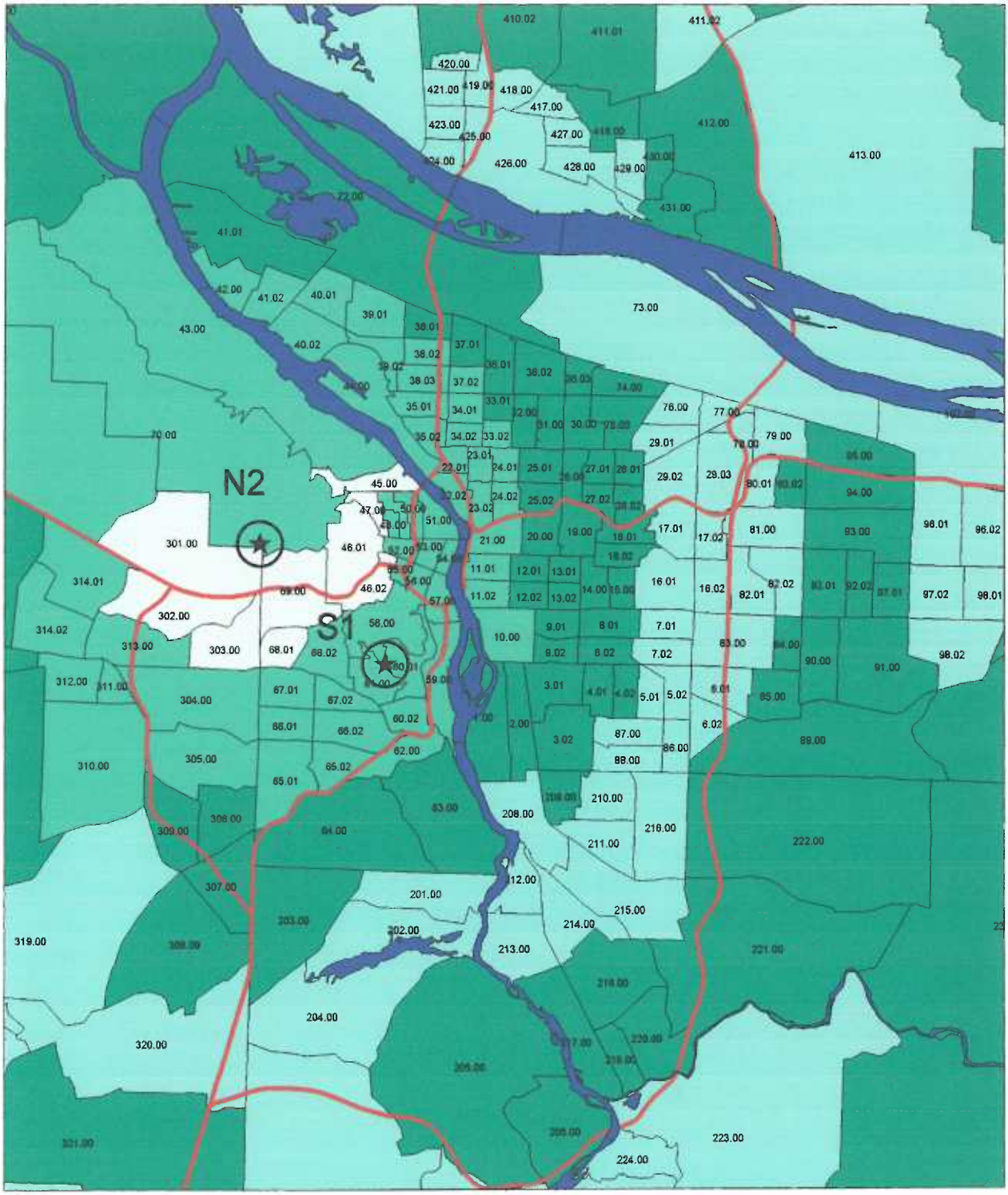
Lung Adenocarcinoma in Females
by Census Tract



Standardized Incidence Ratio

- 72
- 72 - 82
- 82 - 101
- 101 - 108
- 108 - 109

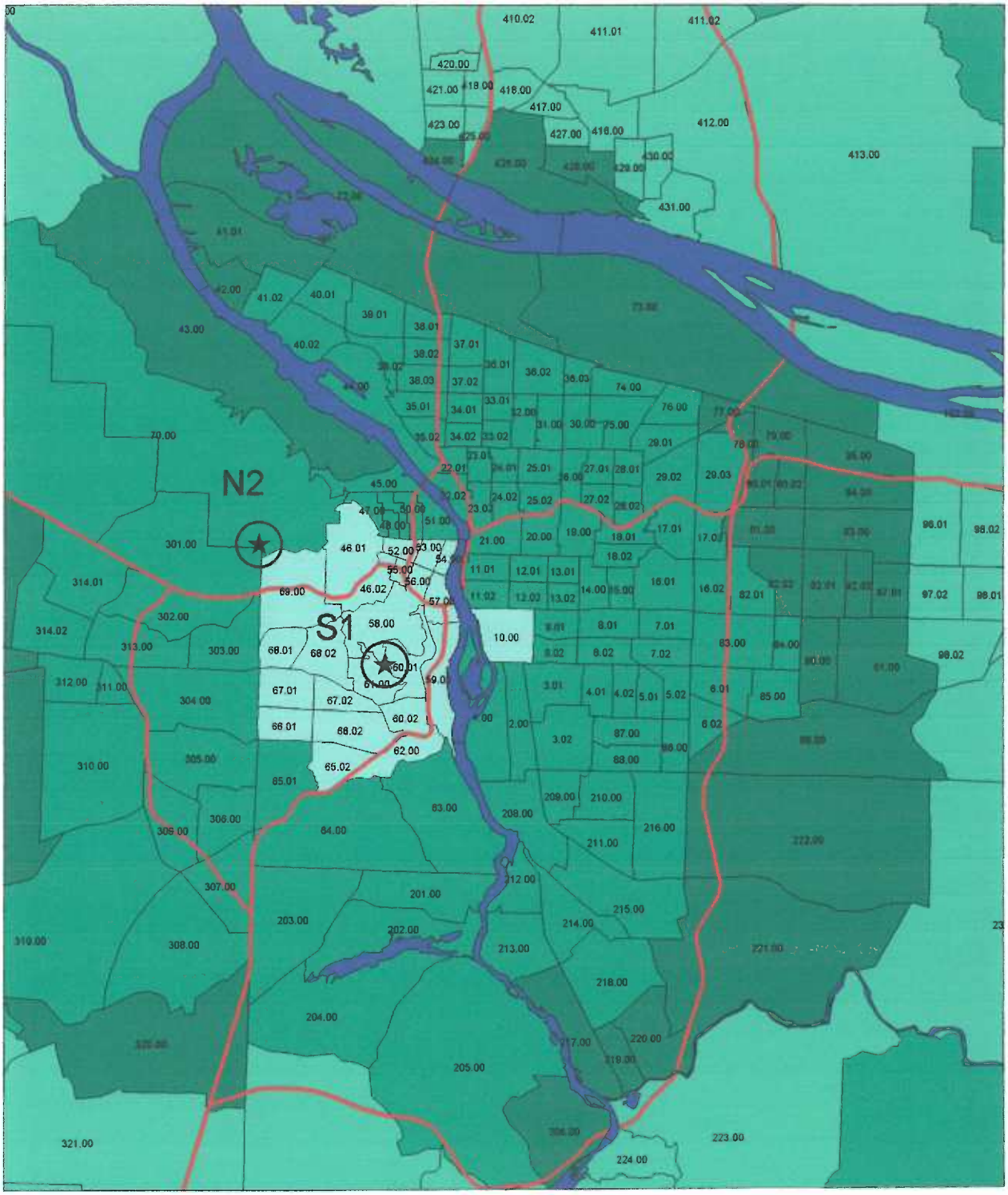
Lung Adenocarcinoma in Males
by N2 Distance Zones



Standardized Incidence Ratio

- 64
- 64 - 90
- 90 - 96
- 96 - 119
- 119 - 140

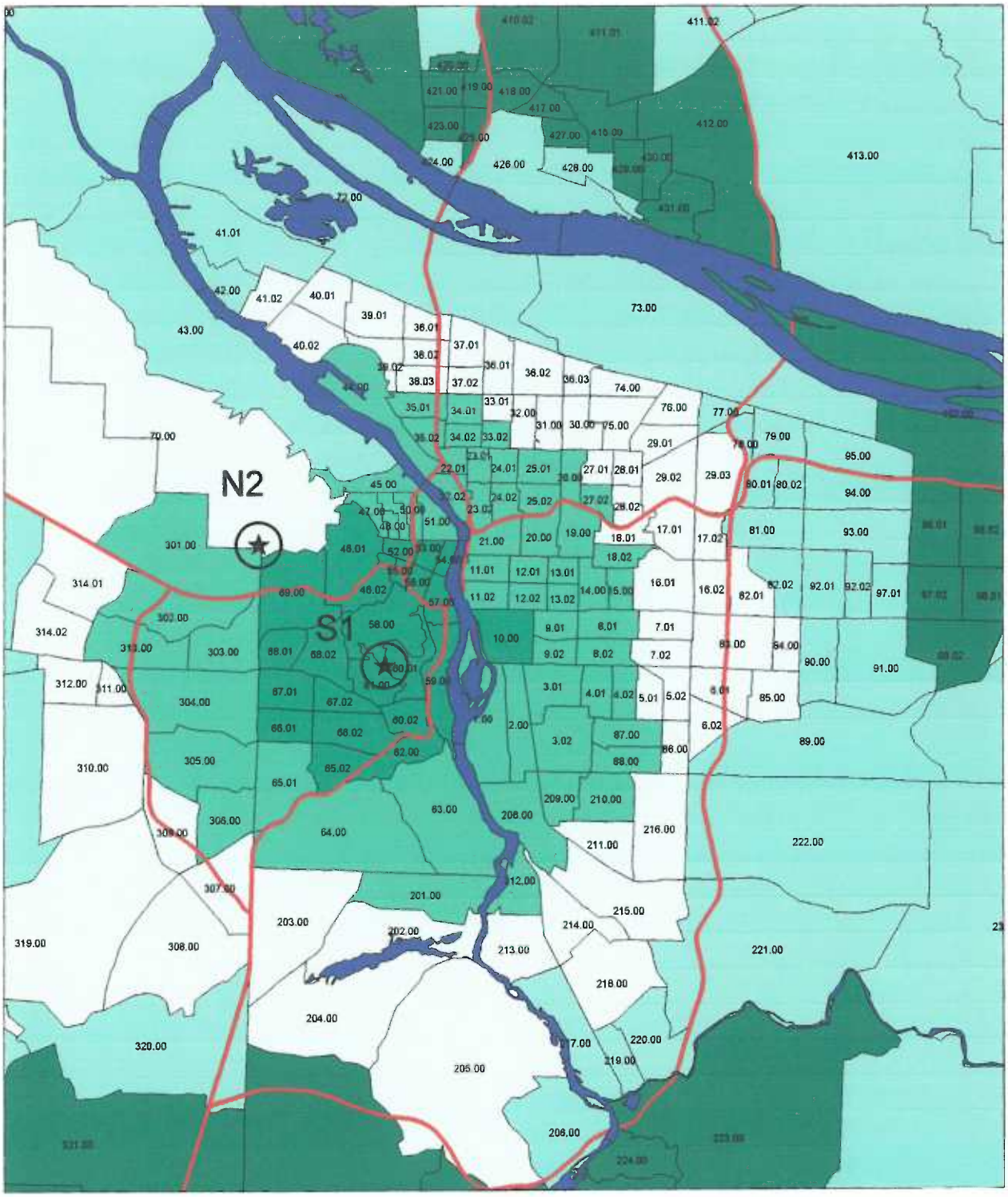
Lung Adenocarcinoma in Females
by N2 Distance Zone



Standardized Incidence Ratio

- 72 - 76
- 76 - 93
- 93 - 99
- 99 - 105
- 105 - 114

Lung Adenocarcinoma in Males
by S1 Distance Zones



Standardized Incidence Ratio

- 90
- 90 - 95
- 95 - 99
- 99 - 115
- 115 - 125

Lung Adenocarcinoma in Females
by S1 Distance Zones