Cancer Occurrence in Offsite Neighborhoods Near the Santa Susana Field Laboratory

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Reasons for Concern

- Intensive testing of rocket fuels
- Heavy usage of solvents, chemicals, metals, radionuclides
- Presumed carcinogen contamination of air, water, and soil
- Surface water drainage to South and East
- Prevailing air dispersion to East
- Contamination of ground water
- Safety conditions quickly relaxed
- Inadequate monitoring
- History of accidents, spills and releases
- History of secrecy and non-responsiveness
- Evidence of excess cancers among workers
  - Lymphoma, lung cancer
Reasons for Skepticism

- Ambiguous and controversial exposure estimates
- Absence of concrete dose-based hypotheses
- Alternative explanations not seriously considered
- Hard to explain how a sufficient dose would occur
- Absence of historical precedents
- Lack of any clear risk found by previous searches
Previous searches were Inconclusive

<table>
<thead>
<tr>
<th>Study</th>
<th>Periods</th>
<th>Locations</th>
<th>Cancers</th>
<th>Conclusions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perkins-Wright</td>
<td>1978-82</td>
<td>5 LA Tracts</td>
<td>11 Sites</td>
<td>Single Tract Bladder 1.5 83-7 Overall: Inconclusive</td>
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<tr>
<td></td>
<td>1983-87</td>
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<tr>
<td>Coye-Goldman</td>
<td>1973-82</td>
<td>Aggregated LA Co. Tracts VEN Co Tracts</td>
<td>14 Sites aggregated</td>
<td>Bladder 1.3 83-88 LA tracts Lung 1.1 88-89 VEN Tracts Suspect Confounding</td>
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<tr>
<td></td>
<td>1983-88</td>
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<td>1988-89</td>
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<tr>
<td>Nasseri</td>
<td>1988-95</td>
<td>Aggregated VEN Co Tracts</td>
<td>12 Sites aggregated</td>
<td>No positive findings</td>
</tr>
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<tr>
<td>Morgenstern</td>
<td>1988-95</td>
<td>Aggregated LA, VEN Blocks by Distance</td>
<td>9 Sites aggregated</td>
<td>Lung 1.1 Middle Belt 88-95 Melanoma 1.2 Middle Belt 96-02 Thyroid ? Proximity effect Aerodigestive? Proximity effect</td>
</tr>
<tr>
<td></td>
<td>1996-02</td>
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</table>
## Problems with Previous searches

<table>
<thead>
<tr>
<th>Study</th>
<th>Problems</th>
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<tbody>
<tr>
<td>Perkins-Wright</td>
<td>Multiple Comparisons, weak associations</td>
</tr>
<tr>
<td></td>
<td>Bias: response to cluster report</td>
</tr>
<tr>
<td></td>
<td>Confounded by Race and Social Class</td>
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<tr>
<td>Coye-Goldman</td>
<td>Multiple Comparisons, weak associations</td>
</tr>
<tr>
<td></td>
<td>Aggregation obfuscates location</td>
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<td>Confounded by Social Class</td>
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<tr>
<td>Nasseri</td>
<td>Multiple Comparisons, weak associations</td>
</tr>
<tr>
<td></td>
<td>Aggregation obfuscates location</td>
</tr>
<tr>
<td></td>
<td>Low statistical power</td>
</tr>
<tr>
<td></td>
<td>Confounded by Social Class</td>
</tr>
<tr>
<td>Morgenstern</td>
<td>Multiple Comparisons, weak associations</td>
</tr>
<tr>
<td></td>
<td>Aggregation obfuscates location; Distance is not dose</td>
</tr>
<tr>
<td></td>
<td>Confounding by Social Class</td>
</tr>
</tbody>
</table>
The Problem of Exposure Dose

- The higher the dose, the more excess cases, the more likely an increase can be measured
Effect of Industrial exposure to hexavalent chromium:
Mean level 790 micrograms/cubic meter of air

Unexposed

2071
25 Cases

UNAFFECTED, 0.988, 99%

LUNG CANCER, 0.012, 1%

Exposed

2042
59 Cases

UNAFFECTED, 0.971, 97%

LUNG CANCER, 0.029, 3%
Effect of Industrial exposure to hexavalent chromium:
Mean level 790 micrograms/cubic meter of air

2042
Exposed
59 Cases

LUNG CANCER, 0.029, 3%
UNAFFECTED, 0.971, 97%

2071
Unexposed
25 Cases

LUNG CANCER, 0.012, 1%
UNAFFECTED, 0.988, 99%
Carcinogenesis increases linearly with dose
Projected effect of Strongest Community Exposure to Hexavalent Chromium

<table>
<thead>
<tr>
<th></th>
<th>Micrograms chromium$^6$/m$^3$</th>
<th>Lung cancers /100,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workplace</td>
<td>790</td>
<td>1700</td>
</tr>
<tr>
<td>Community</td>
<td>0.04</td>
<td>0.09</td>
</tr>
</tbody>
</table>

Thus exposure at the point of the highest known emission of carcinogen in California, about one extra case per million would appear (i.e. in the average census tract, **one extra case every 200 years**).
Dispersion of carcinogen emissions

Point of carcinogen emission

Zone 1: POP 2000
Zone 2: POP 5000 (~ CT SIZE)
Zone 3: POP 15,000
Zone 4: POP 60,000
Emission dose level to individuals is variable

• Chemicals rapidly disperse into air/water

• As the distance from the site increases:
  – More people are exposed
  – Exposure dose is lower

  – Dispersion results in dilution: dose is inversely proportional to distance
Impact of point emission if dose is thought to double the risk

<table>
<thead>
<tr>
<th>Location</th>
<th>Population</th>
<th>Distance</th>
<th>Attributable Risk</th>
<th># Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>At Source</td>
<td>50</td>
<td>0.1 km</td>
<td>100/100,000</td>
<td>0.05</td>
</tr>
<tr>
<td>Zone 1</td>
<td>2000</td>
<td>0.3 km</td>
<td>11/100,000</td>
<td>0.22</td>
</tr>
<tr>
<td>Zone 2</td>
<td>5000</td>
<td>0.5 km</td>
<td>4/100,000</td>
<td>0.20</td>
</tr>
<tr>
<td>Zone 3</td>
<td>15,000</td>
<td>1.0 km</td>
<td>1/100,000</td>
<td>0.15</td>
</tr>
<tr>
<td>Zone 4</td>
<td>60,000</td>
<td>2.0 km</td>
<td>0.25/100,000</td>
<td>0.15</td>
</tr>
<tr>
<td>Zone 5</td>
<td>120,000</td>
<td>3.0 km</td>
<td>0.10/100,000</td>
<td>0.12</td>
</tr>
</tbody>
</table>

No more than a single additional case would be expected
Churchill County (Fallon) ALL Cluster Rate compared to California Rates

- California
- Inyo-Mono Co
- Churchill Co.
Precedents: Environmental cancer clusters do occur (other than occupational risks)

Fallon, NV: 2000-2001, 16 ALL cases occurred, 0.3 expected
   Host to thousands of diverse visitors

Libby, MT: Multiple cases of mesothelioma in a small town
   Tailings of asbestos-containing vermiculite

Cappadocia, Turkey: Cluster of cases of mesothelioma
Greece, Italy, New Caledonia: Clusters of mesothelioma
   From building materials or whitewash with asbestos

Ukraine/Belorus: Localized thyroid cancer in young persons
   From nuclear fallout

Taiwan, Chile, Argentina, Bangladesh: Localized bladder cancer
   Groundwater contaminated with natural arsenic deposits
If dose is usually weak, why are “clusters” found?

Two different circumstances

**Strong** direct exposure, highly targeted at close quarters
- Household asbestos, person to person virus
  - Sufficient dose by *short-term but intense* exposure
  - Sufficient dose to *single families or compounds*

**Strong** indirect or distant exposure, disseminated by air/water/soil
- Chernobyl, waterborne arsenic, asbestos tailings
  - Sufficient dose by *continuous cumulative* exposure over the long-term
  - Sufficient dose disseminated to *multiple adjacent localities*

**Weak** exposure
- Rare cancers undetectable, common ones lost within random variation
Random (Poisson) distribution of Lung Carcinoma occurring in 49 Localities of 5000 Persons each over 5 Years

+ Unexpected Cases?

If the cancer is not rare, the usual cases outnumber the added ones (and vary in number by chance)
The Challenge

• Some offside residents may have been exposed to carcinogens at some dose

• They may well have some added cancer risk.

• The challenge is to see if a measureable and unambiguous increase in risk has been produced.

• Must examine individual neoplasms and individual tracts
To demonstrate an unambiguous association:

- Increase must be at least 50%, a relative risk of 1.5 (there are too many alternative explanations for a weaker link)

- Chance must be excluded

- Adjacent tracts (localities) offsite should have high exposure in common

- Here is a local example
Carcinoma of the Oropharynx
Steps in Linking Environmental Carcinogenicity to a Particular Locality

1. Assess the likelihood that any association between cancer incidence and a residential locality could be explained *by chance*.

2. Ensure that any such association cannot be explained *by a bias*.

3. Ensure that any such association cannot be explained by the *characteristics of local residents*.
1. Assessing chance

- The conventional method (statistically significant with 95% confidence):
  - Statistically significant excess.

- Method is based on the “bell-shaped” normal distribution of chance possibilities—chance can never be ruled out, just quantified.
By convention, “significance” means that if the same circumstance were repeated 100 times, no more than 5% of the results would show the same unusual outcome by chance alone (like the red dots below).

This left area shaded dark blue is 0.025 of the total area under the curve.

This right area shaded dark blue is 0.025 of the total area under the curve.
2. Bias comes in several forms

- Census errors: underestimation of the number of persons, especially high risk persons, makes the excess look too large.

- Multiple comparisons: The more cancers, periods, and tracts tried, the more likely are extreme findings
  - Partial solution: screen by significance in all possible tracts, then calculate how often such extreme results would occur by chance

- Texas sharpshooting: If investigation is initiated by reported “cluster”, we already know the rate is not going to be low, and the test is meaningless
“TEXAS SHARPSHOOTING”

AIM, SHOOT, AND ONLY THEN--
DRAW THE TARGET
Calculate how often such a result would occur by chance

• The following Poisson table gives this percentage for selected observed numbers given the number expected.

• For example, when 2 cases are expected and 6 are observed, 1.6% of localities of that size would find as many or more than 5 by chance.

• That means 160 California localities
Percent of searches expected to find N or more cases observed according to the mean expected

<table>
<thead>
<tr>
<th>Mean expected</th>
<th>1 Obs</th>
<th>2 Obs</th>
<th>3 Obs</th>
<th>4 Obs</th>
<th>5 Obs</th>
<th>6 Obs</th>
<th>7 Obs</th>
<th>8 Obs</th>
<th>9 Obs</th>
<th>10 Obs</th>
<th>11 Obs</th>
<th>12 Obs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>63.2%</td>
<td>26.4%</td>
<td>8.0%</td>
<td>1.9%</td>
<td>0.4%</td>
<td>0.1%</td>
<td>0.01%</td>
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<td></td>
<td></td>
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<tr>
<td>2</td>
<td>59.3%</td>
<td>32.2%</td>
<td>14.2%</td>
<td>5.2%</td>
<td>1.6%</td>
<td>0.4%</td>
<td>0.1%</td>
<td>0.02%</td>
<td>0.01%</td>
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<tr>
<td>3</td>
<td>58.4%</td>
<td>36.0%</td>
<td>19.2%</td>
<td>9.1%</td>
<td>3.4%</td>
<td>1.2%</td>
<td>0.4%</td>
<td>0.1%</td>
<td>0.03%</td>
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<tr>
<td>4</td>
<td>56.7%</td>
<td>37.1%</td>
<td>21.5%</td>
<td>11.1%</td>
<td>5.1%</td>
<td>2.1%</td>
<td>0.8%</td>
<td>0.3%</td>
<td>0.1%</td>
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<tr>
<td>5</td>
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<td></td>
<td></td>
<td>55.8%</td>
<td>38.3%</td>
<td>23.7%</td>
<td>13.3%</td>
<td>6.8%</td>
<td>3.2%</td>
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<td>0.5%</td>
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<tr>
<td>6</td>
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<td>55.4%</td>
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<td>25.5%</td>
<td>15.2%</td>
<td>8.3%</td>
<td>4.2%</td>
<td>1.9%</td>
<td></td>
</tr>
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<td>7</td>
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<td></td>
<td>54.9%</td>
<td>40.0%</td>
<td>27.0%</td>
<td>16.9%</td>
<td>9.8%</td>
<td>5.3%</td>
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<td>54.8%</td>
<td>40.8%</td>
<td>28.4%</td>
<td>18.4%</td>
<td>11.3%</td>
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<td>9</td>
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<td></td>
<td></td>
<td></td>
<td>54.3%</td>
<td>41.1%</td>
<td>29.2%</td>
<td>19.5%</td>
<td></td>
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<tr>
<td>10</td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td>45.3%</td>
<td>32.8%</td>
<td>21.4%</td>
</tr>
</tbody>
</table>
3. Common alternative explanations (important possible confounders)

- Known causes of that particular cancer
  - Unknown by tract: example—smoking

- Race/Ethnicity, (unreliable by tract)
  - Surrogates for known causes—skin color

- Education and Income (unreliable by tract)
  - Surrogates for known causes—age at first child
These characteristics distinguish the residents of neighborhoods

- Neighborhood choice is personal and particular
  - Location, location, location

- Birds of a feather tend to flock together

- Obvious on both County and Census tract levels
  - Ethnicity, education, friends, habits, occupation
Trends in Incidence of Breast Cancer among White Females from California Counties differing in Median Income and Educational Attainment
Trends in Incidence of Malignant Melanoma among Whites from California Counties differing in Median Income and Educational Attainment

![Graph showing trends in incidence of malignant melanoma among whites in California counties. The x-axis represents different periods (1988-94, 1995-01, 2002-8) and the y-axis represents annual age-adjusted incidence per 100K. The graph includes lines for different counties and shows an upward trend in incidence over time.]
Trends in Incidence of Female Lung Cancer among Whites from California Counties differing in Median Income and Educational Attainment

Annual Age-adjusted Incidence/100K

Period

1988-94
1995-01
2002-8
From Counties to Census tracts

• Census tracts are smaller than counties, averaging about 5000 persons but varying from hundreds to tens of thousands.

• For that reason, the variation in incidence comes from three factors:
  – Size of the tract population
  – Chance
  – Causation
Colon Carcinoma in LA

Distribution of census tracts by relative risk (males)

- Pink >1.0, Red > 1.5
Census Tracts at high risk of COL
according to the number of observed and expected cases
Better to show the tracts not by rate but according to the number of cases expected and observed

- For a given expected number, each tract is represented by a dot for the observed number either above or below expected.

- Lines showing both a standard risk (50% increase) and a measure of “significance” are shown. A dot above the lines is shown in red representing a “significant” increase. Those occurring by chance will usually straddle the lines.

- The higher a red dot is above the lines, the higher the incidence in that locality.

- Different cancers show different patterns depending on the concentration of high risk.
Female Colon Cancer

Graph showing observed cases versus expected cases with different lines representing high risk CT, RR=1.5, 95% UCI, and expected cases.
Female Oropharyngeal Cancer
Female Cancer of the Cervix

Graph showing observed cases and expected cases with various lines representing different risk factors.
Male Kaposi Sarcoma

SES = Adj for SES

Expected cases
KAPOSI SARCOMA
Malignant Melanoma

Age-specific incidence by race/ethnicity (males)

- Latino
- Black
- Non-Latino White
- Asian

Age intervals (5 years)
Female Breast Cancer

Age-specific incidence by race/ethnicity (females)

- Latino
- Black
- Non-Latino White
- Asian

age intervals (5 years)
Female Lung Adenocarcinoma

Age-specific incidence by race/ethnicity (females)

- Latino
- Black
- Non-Latino White
- Asian

age intervals (5 years)
CENSUS TRACTS BY SOCIAL CLASS
Malignant Melanoma

Age-adjusted incidence by socio-economic status (males)

age-adjusted incidence (per 100,000)

socio-economic status

high

high-mid

medium

mid-low

low
Female Breast Cancer

Age-adjusted incidence by socio-economic status (females)
Cancers “cluster” for different reasons

- Lung cancer clusters by smoking, race, education
- Oropharynx cancer by smoking/drinking
- Cervical cancer by self/partner’s sexual activity
- Kaposi sarcoma clustered by sexual preference
- Prostate cancer clusters by race, access to care
- Stomach cancer clusters by history of poverty
- Liver cancer clusters by parental ethnicity
- Thyroid cancer clusters by access to screening
- Mesothelioma clusters by occupation
- Melanoma clusters by race and education
- Breast cancer clusters by education/occupation
Characteristics of SSRL Offsite Tracts

• They are not characteristic of their respective Counties in terms of:
  – Income and, doubtless, education
  – Race/ethnicity
Median Family Income of Counties and of High Risk Tracts

- Los Angeles County
- LA Co. High Risk Tracts
- Ventura County
- Ven. Co High Risk Tracts
From where do case reports come?

- California Cancer Registry covers the State
- All cases among residents at diagnosis
- All invasive malignancies (a few benign tumors)
- Mandatory reporting of cancer since 1988
- Hospitals collect reports to maintain certification
- Non-hospital pathologists, death certificates
- Reports returned to the place of residence
- Around 99% complete by regular audits
Malignancies according to Annual (Age-Adjusted) New Cases /100,000

- **50+:** M Prostate, F Breast

- **30-49:** MF Lung, M/F Colorectum

- **10-29:** MF Melanoma, M Oropharynx, M Bladder, F Ovary, F Endometrium, MF Non-Hodgkin Lymphoma, M Leukemia

- **5-9:** M Stomach, M Larynx, M Testes, F Melanoma, F Thyroid

- **<5:** M Thyroid, M Penis, F Stomach, F Larynx, F Bladder, MF Liver, MF Esophagus, MF Gallbladder, MF Hodgkin Lymphoma, MF Eye
Selection of malignancies

• Every cancer has a unique set of causes
  – (Rate of cancer at all sites is not informative)
• Cancers were selected for assessment:
• In all, thirteen different malignancies
  – Four most common cancers
  – Cancers thought caused by chemicals/radiation
<table>
<thead>
<tr>
<th>Neoplasm</th>
<th>Major Causes</th>
<th>Descriptive Predictors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lung</td>
<td>Cigarette smoking</td>
<td>Blue collar occupation</td>
</tr>
<tr>
<td>Bladder</td>
<td>Cigarettes, aniline dyes (rare)</td>
<td>Race</td>
</tr>
<tr>
<td>Pancreas</td>
<td>Cigarette smoking</td>
<td>None strong</td>
</tr>
<tr>
<td>Oropharynx</td>
<td>Tobacco, Alcohol, Virus</td>
<td>None strong</td>
</tr>
<tr>
<td>Leukemia</td>
<td>Genes, benzene, ? virus</td>
<td>None strong</td>
</tr>
<tr>
<td>Breast</td>
<td>Genes, Hormones</td>
<td>Higher education</td>
</tr>
<tr>
<td>Colorectal</td>
<td>Genes, Diet, Activity</td>
<td>None strong</td>
</tr>
<tr>
<td>Prostate</td>
<td>Genes, Diet</td>
<td>Race, Age, Access to screening</td>
</tr>
<tr>
<td>Thyroid</td>
<td>Ionizing radiation (rare)</td>
<td>Access to screening</td>
</tr>
<tr>
<td>Brain</td>
<td>Ionizing Radiation (rare)</td>
<td>None strong</td>
</tr>
<tr>
<td>Liver</td>
<td>Hepatitis B, C viruses</td>
<td>National origin</td>
</tr>
<tr>
<td>NHL</td>
<td>Immune depletion</td>
<td>None strong</td>
</tr>
<tr>
<td>Melanoma</td>
<td>Sunlight, light skin</td>
<td>Race, Higher education</td>
</tr>
</tbody>
</table>
Screening Methods

- Genders assessed separately
- Three time periods:
  - Separate denominators from 3 censuses
- All census tracts within 5 miles of SSFL
  - 1988-95: 22 VEN, 16 LA census tracts
  - 1996-2003: 29 VEN, 17 LA census tracts
  - 2004-2010: 29 VEN, 17 LA census tracts
- Number of comparisons:
  - 130 period-tracts X 24 gender-cancers = 3120 searches
  - Up to 78 (3 per gender-cancer) “significantly” high-risk tracts by chance
Screening Criteria

• Significantly higher rate than County mean
  – Outside the 95% confidence interval (p < 0.05)

• At least a 50% increase in risk (RR > 1.5)

• Histological (Causal) homogeneity
To find a result consistent with local cancer causation by disbursed carcinogen

• Consistent risk over calendar time
• High risk for both genders in the same area
• Higher risk proximate to SSRL
• Geographic clustering of high risk areas
• Pattern consistent with dispersion flow
• We screen by a relative risk (RR) of 1.5, but if RR is below 2.0, any observed case would likely have occurred anyway

• No plausible alternative explanation is available
Reasons for Caution in Assessing Impact

- 3 “Significant” excesses each are expected by chance
- No known clear evidence of personal exposure
- Waterborne and airborne dispersion imprecise
- Dosage is unknown
- Exposed workers are likely to reside together
- Census errors: rapid local growth may distort incidence estimates
- Evaluation is based on residential address at diagnosis
<table>
<thead>
<tr>
<th>Neoplasm</th>
<th>“Significant” tract-periods</th>
<th>In Both genders</th>
<th>In Adjacent tracts</th>
<th>In 2 or more periods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lung</td>
<td>4 (6 exp)</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Bladder</td>
<td>1 (6 exp)</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Pancreas</td>
<td>0 (6 exp)</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Oropharynx</td>
<td>0 (6 exp)</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Leukemia</td>
<td>1 (6 exp)</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Breast</td>
<td>26 (3 exp)</td>
<td>---</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>Colorectal</td>
<td>7 (6 exp)</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Prostate</td>
<td>4 (3 exp)</td>
<td>---</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Thyroid</td>
<td>3 (6 exp)</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Brain</td>
<td>3 (6 exp)</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Liver</td>
<td>0 (6 exp)</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>NHL</td>
<td>2 (6 exp)</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Melanoma</td>
<td>23 (6 exp)</td>
<td>8</td>
<td>17</td>
<td>7</td>
</tr>
<tr>
<td>Period</td>
<td>Males</td>
<td>Females</td>
<td>Both</td>
<td></td>
</tr>
<tr>
<td>----------</td>
<td>-------</td>
<td>---------</td>
<td>------</td>
<td></td>
</tr>
<tr>
<td>1988-1995</td>
<td><img src="image" alt="Blue Triangle" /></td>
<td><img src="image" alt="Yellow Triangle" /></td>
<td><img src="image" alt="Red Triangle" /></td>
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</tr>
<tr>
<td>1996-2003</td>
<td><img src="image" alt="Blue Circle" /></td>
<td><img src="image" alt="Yellow Circle" /></td>
<td><img src="image" alt="Red Circle" /></td>
<td></td>
</tr>
<tr>
<td>2004-2010</td>
<td><img src="image" alt="Blue Square" /></td>
<td><img src="image" alt="Yellow Square" /></td>
<td><img src="image" alt="Red Square" /></td>
<td></td>
</tr>
</tbody>
</table>
Malignant Melanoma 1988-1995

1 mi
2 mi
3 mi
4 mi
5 mi
Malignant Melanoma

1996-2003

Distance:
1 mi
2 mi
3 mi
4 mi
5 mi
Malignant Melanoma

- High risk CT
- RR=1.5
- 95% UCI
- Expected

SES=Raw

Observed cases vs. Expected cases graph.
Malignant Melanoma
Malignant Melanoma - Adjusted for SES

SES = Adj for SES

Expected cases
Breast cancer 1988-1995
Female Breast Cancer

---

**SES=Raw**

- High risk CT
- RR=1.5
- 95% UCI
- Expected

- **Observed cases**
  - 300
  - 250
  - 200
  - 150
  - 100
  - 50
  - 0

- **Expected cases**
  - 0
  - 20
  - 40
  - 60
  - 80
  - 100
  - 120
Female Breast Cancer

SES = Adj for SES

Expected cases
Colorectal Cancer
FEMALE LUNG

![Graph showing trends in female lung data from 1988-95 to 2004-10 with different categories indicated by line types and colors.](image-url)
MALE BRAIN

[Graph showing data trends for different categories labeled LA TOT, LA WH, LA HSES, VEN TOT, VEN WH, VEN HSES over different time periods: 88-95, 96-03, 04-10.]
MALE LEUKEMIA

Graph showing trends in male leukemia rates from 1988-1995 to 2004-2010 for various categories.
These cancer rubrics oversimplify causal heterogeneity

- Brain: many reported cases are benign, slow-growing tumors with different causes
- Non-Hodgkin lymphoma includes at least five different malignancies known to have different causes
- Leukemia also is made up of three common and several uncommon varieties
- In this case, each the apparently “high-risk” tracts were no more numerous than expected by chance, and included cases of diverse, most having no known environmental causation
Excess of bladder cancer in one tract in 2004-2010

- Extreme finding: RR >5
- Case tumors had the same common histology
- Most residences scattered, but several are within one mile
- The most prevalent cause of bladder cancer is smoking
- Environmental causes are industrial, waterborne arsenic
- Diagnoses not clustered in time
- The tract is more than 5 miles to the west of SSFL
- Residential community: no known exposure, specifically no high arsenic in tap water, no local industry, no increase in kidney cancer (another arsenic outcome)
- 66% of the cases were >75 at diagnosis, and all but one of those was over 85.
- Census may have undercounted seniors
<table>
<thead>
<tr>
<th>Neoplasm</th>
<th>“Significant” tract-periods</th>
<th>Observed/Expected number per tract</th>
<th>Interpretation</th>
<th>Estimated number of CA tracts with that many or more cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>NHL</td>
<td>2 (3 exp. by chance)</td>
<td>8/2.5</td>
<td>No clustering of high-risk tracts No evidence of proximity to SSFL Mixture of cell types, no trend</td>
<td>50-100</td>
</tr>
<tr>
<td></td>
<td>12/5.3</td>
<td></td>
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</tr>
<tr>
<td>Brain</td>
<td>3 (3 exp. by chance)</td>
<td>6/0.9</td>
<td>No clustering of high-risk tracts No consistent proximity to SSFL Mixture of cell types, no trend</td>
<td>10-50</td>
</tr>
<tr>
<td></td>
<td>8/2.3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>11/3.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leukemia</td>
<td>1 (3 exp. by chance)</td>
<td>7/1.3</td>
<td>No clustering of high risk tracts No evidence of proximity to SSFL Mixture of cell types, no trend</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bladder</td>
<td>1 (3 exp. by chance)</td>
<td>11/2.5</td>
<td>No clustering of high risk tracts No evidence of proximity to SSFL No evidence of carcinogens Preponderance of elderly cases ? Smoking, census error</td>
<td>1-2</td>
</tr>
<tr>
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</tr>
</tbody>
</table>
Conclusion

• It is not possible to completely rule out any offsite carcinogenic effects from SSFL.

• No evidence of measureable offsite cancer causation occurring as a result of emissions from the SSFL was found.

• Further, no evidence of any cancer causation by any environmental factor was found.