Estimate of the Number and Costs of Excess Cancer Deaths Associated with Residence in the Oil-producing Areas of the Sucumbios and Orellana Provinces of Ecuador

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I was retained by plaintiff counsel to prepare this report.

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The intent of this document is to present estimates of the number of excess cancer deaths of residents in the oil-producing area of the Sucumbios and Orellana provinces of Ecuador, the aggregate value of those deaths, and the methods underlying the computation of these estimates.

The aggregate cost estimates depend upon the size of the geographic region containing the population residing near the oil-producing facilities and the last year of entry of newly exposed persons. The deaths upon which these estimated costs are based include all excess cancer deaths—all who have already died as well as all who will die. The estimates are shown in the following table; the amounts shown are billions of 2009 dollars.

Last Year of Entry of Newly Exposed Persons	*Persons Residing in the Concession Area*	*Persons Residing Within 5 km of Oil Facilities*
2009	$46.9	$27.5
1990	$20.7	$12.1

The Geographic Areas Covered by These Estimates

The oil-producing areas in question are the Texaco 1973 Concession Area (hereafter, the C.A.) and a somewhat smaller area that includes the land within 5 kilometers (km) of the exploration and production facilities (including the wells, holding pits, stations, and pipelines). The C.A. is shown in the map "Concesion de Texaco 1973" and the "within 5 km area" in the map "Mapa del Area de Influencia de las Operactiones Realizadas por Texaco."

The C.A. is contained in four provinces (Sucumbios, Orellana, Napo, and Pastaza). Most of the C.A. is in Sucumbios and Orellana with only very small portions in Napo and Pastaza. Within Sucumbios, the C.A. is contained mainly in the cantons of Lago Agrio and Shushufindi with a small portion in Cascales. Within Orellana, the C.A. is predominately in the La Joya de Los Sachas and Orellana cantons. According to the geographic information system (GIS) that prepared the map "Concesion de Texaco 1973," the area of the C.A. is 491,365.69 hectares (Ha) or 4,914 square kilometers (km^2).

The area within 5 km of the production facilities is shown in the map "Mapa del Area de Influencia de las Operactiones Realizadas por Texaco." The GIS system that produced this map reports that the "within 5 km area" is 288,256.60 Ha or 2,883 km^2. Note that the "within 5 km area" is contained within the C.A.

The Range of Years Covered by These Estimates

Exploration for oil began prior to 1967 when commercially viable reserves were found. Commercial production began in 1972 when a pipeline from the C.A. to the Pacific over the Andes was completed. Oil production and expansion of the production facilities continues to the present day. Consequently, the number of excess deaths will be estimated from 1967 to 2009 and from 1967 to the year of the last excess cancer death.

Computational Approach and Quantities Needed to Compute the Estimates

The estimate presented here employs standard actuarial life-table methodology to perform the required computations (see Elandt-Johnson and Johnson, 1980, pages 83 to 110 and pages 294 to 307). The quantities needed to perform the computations include:

1. An estimate of the number of persons residing in the C.A. and within the 5 km area by year from 1967 to 2009;
2. The age distribution of the persons residing in the C.A. and within the 5 km area; because the 5 km area is within the C.A., the same distribution will be used for both and it varies by year;
3. Estimates of the age-specific total mortality rates and the age-specific rates for all malignant neoplasms; these vary by year;
4. Estimate of the age-specific excess risk of cancer.

How each of these quantities is estimated will now be described.

1: Number of Persons Residing in the C.A. and Within the 5 km Areas

The Instituto Nacional de Estadistica y Censos (INEC), the Ecuadorian equivalent of the U.S. Census Bureau, National Center for Health Statistics, and Bureau of Labor Statistics, makes available the computer files for both the 1990 and 2001 Ecuadorian national censuses on their web site (www.inec.gov.ec). In addition, the INEC web site also provides a document comparing the results of the 1990 and 2001 censuses ("VI Censo de Poblacion y V de Vivienda 2001: Analysis Resultados Definitivos") and two documents reporting the historical and projected populations from 1950 to 2025 ("Estimaciones y Proyecciones de Poblacion: 1950-2025" and "Proyecciones de Poblacion por Provincias, Cantones, Areas, Sexo y Grupos de Edad: 2001-2010"). Finally, the INEC web site also makes available cartographic boundary files for the shapes and spatial locations of the three level political geography of Ecuador (provinces > cantons > parishes).

The map giving the location and boundaries of the C.A. reports its area as 4,914 km^2; if an estimate of the population density in the C.A. at some point in time were available (in persons per km^2), the product of the two would estimate the population at that time. The records in the computer file of the 2001 census data contain a field giving the six-digit code (PPCCpp: two digits for Province, two for Canton in the province, and two for parish in the canton) for the place of residence. Consequently, the number of persons residing in each parish in 2001 can be computed.

The cartographic boundary files were used to prepare a map showing the locations of the parishes in Sucombios and Orellana and their six-digit codes appeared as labels for the parishes. The outline of the C.A. was overlaid on this parish map and it was determined which of the parishes are contained wholly or partially within the C.A. The results of this determination are shown in the Table 1.

Table 1:
List of Parishes Contained Wholly or Partly in the 1973 Concession Area

Parish Code	Inclusion Weight	Population in 2001	Area (sq km)
210150	0.5	39,860	379.8
210152	1.0	3,084	248.8
210153	0.5	5,492	515.2
210155	1.0	5,569	451.1
210157	0.2	2,213	445.0
210158	0.5	3,759	235.4
210450	1.0	18,931	452.4
210451	0.5	3,398	601.3
210453	0.2	2,402	628.1
210454	1.0	2,485	66.4
210455	1.0	3,008	122.5
210650	0.2	4,586	1085.6
210652	0.5	2,381	109.6
220150	1.0	27,020	146.2
220151	0.5	10,431	1236.6
220152	1.0	3,914	409.4
220350	1.0	12,409	196.4
220351	1.0	5,443	76.0
220352	0.5	1,570	98.3
220353	1.0	2,785	134.9
220354	0.2	3,421	284.4
220452	0.5	1,956	194.0
Weighted Total		121,596	4,478
Population Density			27.2

The populations are tabulated from the 2001 census file; the areas of the parishes are contained in the cartographic boundary files. The Inclusion Weight for a parish has a value of 1.0 if the parish is contained wholly or predominantly inside the C.A. boundaries; a value of 0.5 is assigned if the parish is approximately half-in and half-out of the C.A.; and a value of 0.2 if less than half of the parish is contained in the C.A. The two totals are weighted by the Inclusion Weights and the Population Density is computed as 121,596/4,478 = 27.2.

Multiplying the area of the C.A. (4,914 km^2) by the population density (27.2 persons/km^2) yields an estimate of the population of C.A. as 133,432 persons in 2001. Similarly, multiplying the within 5 km area (2,883 km^2) by the population density produces a population estimate of 78,277 persons in 2001. However, these populations were smaller prior to 2001 and larger after. One approach was used to estimate the earlier populations and another to estimate the later. First, we will consider the period from 1967 to 2001.

The first two tables of the publication "Proyecciones de Poblacion por Provincias, Cantones, Areas, Sexo, y Grupos de Edad" present population totals by province for the 1990 (in Cuadro 1) and 2001 (in Cuadro 2) censuses. Sucumbios existed as a province in 1990 and 2001, but Orellana did not; it was formed in 1998 by separating certain cantons from Napo. Nonetheless, Cuadro 1 shows the population for the geography that would become Orellana. The populations for Sucumbios and Orellana in 1990 and 2001 are shown in the Table 2.

Table 2:
Populations of Scumbios and Orellana in 1990 and 2001 and Their Growth Rates

	Year of Census		*Growth Rate*	
Province	*1990*	*2001*	*11 Years*	*Per Year*
Sucumbios	77,148	128,995	1.672	1.048
Orellana	48,757	86,493	1.774	1.053
Total	125,905	215,488	1.712	1.050

Also shown are the growth rates (actually, growth "multipliers") over 11 years (from 1990 to 2001) and for a single year. The annual growth rate for the total of the two provinces is about a 5% increase per year. Assuming that the populations of the C.A. and the within 5 km areas are a relatively constant fraction of the Sucumbios+Orellana total, the growth rate can be used to extrapolate the 2001 C.A. population figure backwards to 1967 (previous year population = current year population divided by 1.05).

A different approach was used to estimate the population from 2001 to 2009. A table in "Proyeccion de Poblacion por Provincias, Cantones, Areas, Sexo y Grupos de Edad" reports projections of the population from 2001 to 2010 down to the level of the canton. The total of the projections for the cantons of Cascales, Lago Agrio, Shushufindi, La Joya de los Sachas, and Orellana was used as an index series for the populations within the C.A. and within the 5 km area. The results of these two approaches are shown in Table 3 on the following page.

Table 3:
Index Series Used to Estimate the Year-to-Year Increases in the Populations and the Resulting Yearly Estimates

	Index Series		Within	Within 5
Year	67 to 01	01 to 09	the C.A.	km Area
1967	40,932		25,346	14,869
1968	42,982		26,615	15,613
1969	45,134		27,947	16,395
1970	47,393		29,346	17,216
1971	49,766		30,816	18,078
1972	52,257		32,358	18,983
1973	54,874		33,978	19,933
1974	57,621		35,680	20,931
1975	60,506		37,466	21,979
1976	63,535		39,342	23,079
1977	66,716		41,311	24,235
1978	70,056		43,380	25,448
1979	73,564		45,551	26,722
1980	77,247		47,832	28,060
1981	81,114		50,227	29,465
1982	85,175		52,741	30,940
1983	89,439		55,382	32,489
1984	93,917		58,154	34,116
1985	98,619		61,066	35,824
1986	103,557		64,123	37,618
1987	108,741		67,334	39,501
1988	114,185		70,705	41,478
1989	119,902		74,245	43,555
1990	**125,905**		77,962	45,736
1991	132,208		81,865	48,026
1992	138,828		85,963	50,430
1993	145,778		90,267	52,955
1994	153,076		94,787	55,606
1995	160,740		99,532	58,390
1996	168,788		104,515	61,313
1997	177,238		109,748	64,383
1998	186,112		115,242	67,606
1999	195,430		121,012	70,991
2000	205,214		127,071	74,545
2001	**215,488**	180,949	133,432	78,277
2002		183,369	135,217	79,324
2003		191,651	141,324	82,907
2004		200,013	147,490	86,524
2005		207,438	152,965	89,736
2006		214,253	157,991	92,684
2007		222,531	164,095	96,265
2008		229,854	169,495	99,433
2009		236,422	174,338	102,275

2: The Distribution of Age by Year

Two different methods were used to produce the age distributions, one based on the 1990 and 2001 censuses and a second based on the 2001 to 2010 population projections produced by the INEC. Table 4 shows the distribution of age for the total population residing in the provinces of Sucumbios, Napo, and Orellana (Suc. + Napo + Ore. in the table). Orellana was split from Napo in 1998; consequently, the geographic region covered by the population is the same between the two censuses.

Table 4:
Age Distribution in 1990 and 2001 for the Population of Sucumbios, Napo, and Orellana

Age Range	Suc. + Napo + Ore. 1990	Suc. + Napo + Ore. 2001
0 to 4	17.0%	14.2%
5 to 9	15.8%	13.9%
10 to 14	13.2%	12.6%
15 to 19	10.9%	10.6%
20 to 24	9.0%	9.4%
25 to 29	8.2%	7.8%
30 to 34	6.4%	6.6%
35 to 39	5.3%	6.0%
40 to 44	4.0%	4.8%
45 to 49	3.1%	3.6%
50 to 54	2.4%	2.9%
55 to 59	1.6%	2.1%
60 to 64	1.2%	1.7%
65 to 69	0.7%	1.2%
70 to 74	0.5%	0.9%
75 to 79	0.3%	0.6%
80 & up	0.4%	1.1%
Total	100.0%	100.0%

Each column of the table reports the distribution of the ages in the region expressed as a percent—the first column based on the 1990 census and the second on the 2001 census. These populations are young, but getting older. Were the two distributions the same, it would not be necessary to trend them, but they do differ and the shift from younger to older must be reflected in the age distributions.

The distributions for the years between 1990 and 2001 were computed by linear interpolation (i.e., a straight line between the 1990 figure and the 2001 figure for the same age range). The same straight lines were used to extrapolate backwards from 1990 to 1989, 1988, 1987, and 1986. The distribution for 1986 was used as the distribution for the years from 1967 to 1985.

A series of tables in the INEC report "Proyecciones de Poblacion por Provincias, Cantones, Areas, Sexo y Grupos de Edad" gives the population projections by year (2001 to 2010), by age group (as in the preceding table), and by province. The projections for Sucumbios and Orellana were added and the percentage distributions were computed from these projections for the years from 2001 to 2010. The distributions for the years from 2011 to 2020 were estimated by sixteen linear trends—one for each of the sixteen age groups.

3: Mortality Rates for All Causes of Death and for All Malignant Neoplasms

Age-specific mortality rates are computed by dividing the number of deaths for a specified range of ages (e.g., 25 to 29), over a specific interval of time (e.g., during 2001), and, perhaps, for a specified cause (e.g., any malignant neoplasm) by the population in the same age range for the same time interval. The INEC makes available on their web site files containing a record for each recorded death; these files span the period from 1990 to 2009. Each record contains a cause of death (ICD-9 from 1990 to 1996, ICD-10 from 1997 to 2009), the age of the decedent at death, and the decedent's usual place of residence ("lughab"). Table 5 presents the mortality rates computed from the 1990 "deaths" file and 1990 census file and for the 2001 "deaths" file and 2001 census. The geography includes the entire country of Ecuador. Shown are age-specific rates for all causes (i.e., total deaths) and for all cancers[1]. The numbers shown report the number of deaths per 100,000 persons; because cancers are a subset of total, the cancer rates are necessarily less than the total rates. The rates in Table 5 also demonstrate why it is necessary to trend them over time—generally a 2001 rate is less than its corresponding 1990 rate—sometimes substantially so.

[1] For ICD-9, malignant neoplasms included ICD-9 codes 140 to 209; benign neoplasms (210 to 229) and carcinomas in situ (230 to 234) were not included as malignancies. For ICD-10, all codes beginning with the letter C were counted.

Table 5:
Age-specific Total Mortality Rates (All Cause) and Cancer Mortality Rates for 1990 and 2001

Age Range	1990		2001	
	Total	Cancers	Total	Cancers
0 to 4	905.7	5.3	516.9	4.1
5 to 9	74.1	3.6	53.4	4.8
10 to 14	68.0	4.2	53.8	4.3
15 to 19	117.7	7.1	117.0	6.5
20 to 24	172.4	8.7	156.4	7.1
25 to 29	176.8	7.7	188.5	12.5
30 to 34	217.5	16.4	197.9	15.9
35 to 39	271.3	27.5	230.7	26.2
40 to 44	348.0	46.4	281.7	38.6
45 to 49	465.8	71.8	386.1	64.2
50 to 54	644.2	108.5	523.1	90.7
55 to 59	955.4	187.0	763.4	147.9
60 to 64	1295.2	249.0	1038.9	190.7
65 to 69	2072.7	400.6	1509.2	309.8
70 to 74	3110.8	579.3	2263.1	444.3
75 to 79	5063.3	795.4	3325.0	571.5
80 & up	10319.6	999.3	5756.2	639.8

The "deaths" files are available for each year from 1990 to 2009; consequently, counts by age and cause of death can be computed for each year. What is needed to compute the mortality rates are their denominators—population estimates (or counts) for each age range and year.

The INEC report "Estimacionnes y Proyecciones de Poblacion: 1950-2025" contains a table reporting population estimates by age group for 1965, 1970, 1975, 1980, …, and 2000. Two of these tables fill some of the gap between 1990 and 2001 (1995, 2000). Linear interpolation was used to estimate the populations between 1990 and 1995 (i.e., along a straight line for each group) and again between 1995 and 2000. The population projections are reported by age range for each year from 2001 to 2010 in the INEC report "Proyecciones de Poblacion por Provincias, Cantones, Areas, Sexo y Grupos de Edad;" these projections serve as the denominators from 2002 to 2009. At this point, the all cause and all cancers mortality rates have been determined for each year from 1990 to 2009. These rates must now be trended backwards (to 1967) and forwards (until the year of the last death).

Over the 1990 to 2009 period, a multiplicative model best fit the year-to-year trend for the all cause rates. That is, the next year's rate is the product of a constant (less than one because the rates are becoming smaller) multiplied by this year's rate. The multiplier depends on the age range, so it must be estimated for each range. These models (there are 16 of them) were used to trend the all cause rates backwards five year (to 1985) and forwards five years (to 2014). The rates for the period from 1967 to 1984 were assumed to be equal to the 1985 rates and the rates from 2015 to the end were assumed to be equal to the 2014 rates.

A linear trend best fit the cancer mortality rates; that is, the next year's rate is this year's rate less a small constant. Again, the constant varies by age range and 16 of them must be determined in all. As in the case of the all cause rates, the trending went backwards and forwards only five years. The cancer rates for the years from 1967 to 1984 were assumed to be equal to the 1985 rates and the rates from 2015 to the end were assumed to be the same as the 2014 rates.

4: Estimates of the Excess Cancer Risk Associated with Residence in Oil-producing Areas

An article by Hurtig and San Sebastian (2002) presents the statistics needed to compute an estimate of the excess cancer risk associated with residence near the oil fields. They compared the cancer experience of persons residing in the four cantons of Lago Agrio, Shushufindi, La Joya de los Sachas, and Orellana—the four cantons that contain most of the C.A.—to the cancer experience of persons residing in eleven cantons with no oil production facilities. Hurtig and San Sebastian (2002, page 1023) report that the population of the four "exposed" cantons was 118,264 in 1992. Two of the cantons are in Sucumbios and two in Orellana. These four cantons are by far the most populous of the cantons in these two provinces and the combined population of the four is larger than either of the two areas used for the projections reported here.

The statistics needed to compute age-specific excess risk are shown in the two graphs (one for males and one for females) of Figure 2 of their article. Excess risk is computed as the ratio of the cancer incidence rate for those residing near an oil field ("Exposed" in Figure 2) divided by the rate for the same age for a control group not residing near a field ("Non-exposed" in Figure 2). Because the excess risk may depend on age, the two charts were digitized yielding four sets of values (men/women by exposed/non-exposed). For both the men and women the exposed and non-exposed rates were identical until the 50 to 54 age group; consequently, the excess risk was set to 1 (i.e., no excess risk) for ages less than 50. For the age groups from 50 to 54 and up, the results for men and women were averaged, and then the ratio of mean exposed to mean non-exposed was computed for each age group. The results are shown in Table 6.

Estimates of the Number and Costs of Excess Cancer Deaths in the Oil-producing Areas of Sucumbios and Orellana Provinces

Overview of the Actuarial/Life Table Methods and Three Complications

The computations needed to compute the excess cancer deaths by year are relatively straightforward and are described in Chapters 4 and 10 of Elandt-Johnson and Johnson (1980). There are, however, some complications that merit discussion. We begin with the first year of the computations, 1967, for the 25,346 estimated residents of the C.A.

The 1967 is the year of entry of the 25,346 persons. In essence, the number of deaths to be expected during a year will be calculated for that year and the number still living will be passed to the next year of death and the process is repeated, going for as many years forward as necessary until all the original population is deceased.

The first complication is this: the initial population will be split into 16 separate age groups using the age distribution for the year of entry. After the split, the same calculations are done for each of the 16 age groups. Note, however, that the mortality rates will differ from one age group to the next (because the starting ages differ) and, with each passing possible year of death, the persons in an age group will get older by one year. For example, consider the 0 to 4 age group. In 1967, they begin with an average age of 2; at the end of the first possible year of death (i.e., the end of 1967) they are a year older and continue to gain one year of age with each additional year. Although, the splitting up of the population by age seems to complicate things, the treatment of each of the groups is essentially the same; only the mortality rates and excess risk factors will differ as they are dependent on age.

At each possible year of death, the expected number of excess cancer deaths, "normal" cancer deaths, and deaths due to all other causes will be determined. The second complication concerns the computation of the excess cancer deaths. For most cancers, there is a latency period between the onset of exposure to the carcinogen and the manifestation of the cancer. The minimum latency tends to be short (3 to 4 years) for cancers of the blood and longer (10 years or more) for cancers of "solid" tissues. This effect was modeled by ramping up the application of the cancer excess risk factor according to the following chart. The chart shows the magnitude of the impact of the excess risk ranging from 0 (no excess risk) to 1 (full application of the excess risk factor).

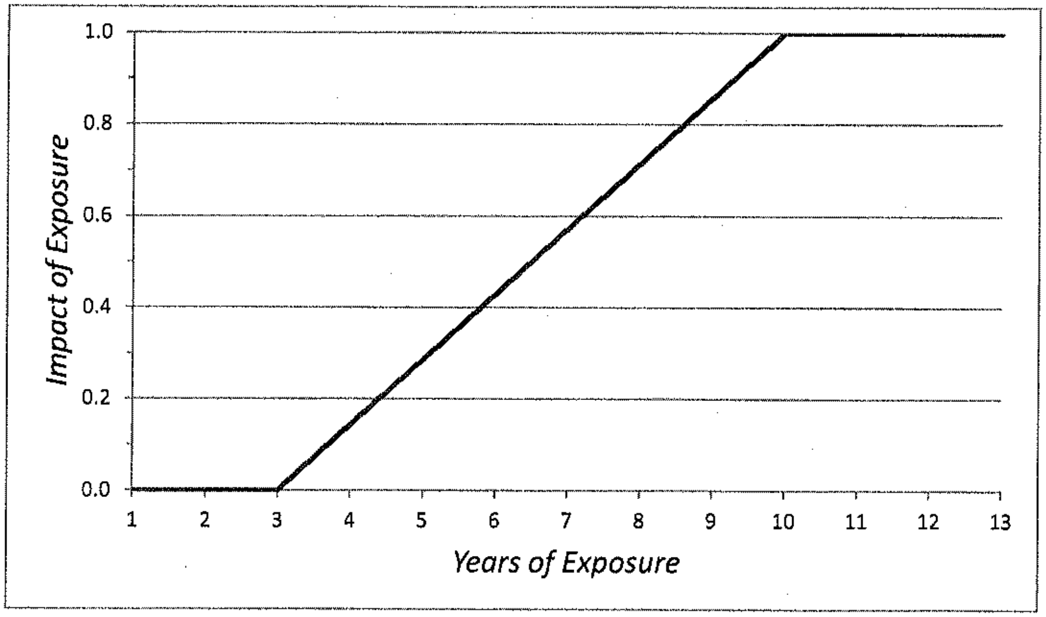
Table 6:
Age-specific Excess Risk Factors

Age Range	*Excess Risk*
0 to 49	1.00
50 to 54	1.65
55 to 59	1.51
60 to 64	1.46
65 to 69	2.64
70 to 74	1.61
75 & Up	0.75

These excess risk factors are used in the following way. If a person resides in an area far from an oil field, then that person's cancer mortality rate may be read directly from Table 5. For example, someone between the ages of 60 and 64 had a cancer mortality rate of 190.7 per 100,000 in 2001. On the other hand, if the person resides near an oil field, that person's cancer mortality rate is 2.64×190.7 = 503.4 per 100,000—more than twice as large.

There are two points that should be made here. First, the excess risk estimate is based on cancer incidence—not cancer mortality. That is, the numerators of the age-specific incidence rates include both deceased and living persons. Consequently, excess risk factors based on cancer mortality rates (i.e., based only on deceased persons) might differ somewhat from those shown in Table 6. However, it is very likely that the mortality-based excess risk factors would be nearly equal to incidence-based ones. This is because it is also likely that the proportion of deceased persons within the "exposed" cantons is nearly the same as the proportion of deceased in the "non-exposed" cantons. These nearly equal proportions cancel each other out with the computation of the excess risk factors, yielding nearly equal excess risks, whether based on incidence or mortality.

Second, the geographic area spanned by the Hurtig and San Sebastian (2002) study is much larger and includes many more people than does the larger of the two projection areas/populations used in this study (i.e., the C.A.). For example, the population in the four Hurtig-San Sebastian cantons is about 38% larger than the 1992 estimate of the population of the C.A. (118,264 compared to 85,693; see Table 3). This, of course, implies that were the population in the four cantons used to provide the starting populations for the excess cancer death estimates, the corresponding results would be larger than any reported here. It is recommended that the use of the populations in the four cantons as the basis for excess cancer death estimates be undertaken.



There is no impact of excess risk until the fourth year of exposure. The full effect of the excess risk factor is not reached until the tenth year of exposure.

The third complication concerns the "carry-over" of still living people who entered the process in prior years. Consider the cohort of 25,346 persons who began at the start of 1967. Clearly, a large number of these people will still be alive at the end of 1967/start of 1968. The estimated population size for 1968, 26,615 persons will include those still living from 1967 plus births and new arrivals to the area. Consequently, the number of new persons entering in 1968 is not 26,615, but a much smaller number of new entrants. The population entering in 1969 includes still living persons from both 1967 and 1968. Both of these must be removed to estimate the number of new persons in 1969. The computations were organized to prevent the multiple-counting of carry-overs from previous years of entry.

Estimates of the Number of Excess Cancer Deaths

Estimates of the number of excess cancer deaths will be determined for two different populations at risk—those residing in the C.A. and those residing within 5 km of the oil-production facilities—and for two last years of entry of the exposed population—2009 and 1990. What is meant by the last year of entry is this: no newly exposed persons will enter the computations after the "cutoff" year.

Consider, for example, the 2009 cutoff. Clearly, there are people residing in the C.A. now (the 2010 estimate is 158,517 persons). As described earlier, most of these are "carry-overs" from prior years of entry, but some of them are new arrivals (e.g., births and in-migrants). Any new arrivals after 2009 are not included in the computations producing the estimates reported here. If they were to be included, the estimates would be much, much larger than any reported here. In fact, they would not even begin to decline until well after environmental remediation was complete.

In addition to the use of the entire populations of Lago Agrio, Shushufindi, La Joya de los Sachas, and Orellana as the population base for the excess cancer estimates, it is further recommended that the impact of potential future remediation be considered. For example, it would be possible to assume that remediation commenced in 2011 and was completed by 2020. During this period, new arrivals would continue to be at an excess risk of cancer, but this risk would be diminished over time as remediation progressed. Even if modeling the impact of potential remediation, projections based on these assumptions would be larger than any reported here because new persons would continue to be added to the population at risk from 2010 until the proposed remediation was complete.

The excess cancer estimates are shown in Table 7.

Table 7:
Estimates of the Number of Excess Cancer Deaths From 1967 to 2009 and From 1967 to the Last Death for the Two Areas and Two Last Years of Entry of the Exposed Population

Year of Last Entry of Exposed Population	*Excess Cancers From 1967 to*	*Within the C.A.*	*Within 5 km*
2009	*2009*	776	453
	Last Death	6,695	3,933
1990	*2009*	706	411
	Last Death	2,961	1,732

In spite of the fact that no new persons are entered and "at risk" after last entry years, the deaths of all those already present and at risk will continue well into the future. In fact, the peak of the excess cancer deaths is in 2030s for the 2009 last entry year and the last excess cancer death won't occur until 2080.

This duration may seem surprising, but consider the history of asbestos-related cancers in the U.S.—especially mesothelioma, a rare but nearly always fatal cancer of the lining protecting many internal organs (e.g., the lungs). By 1984, asbestos had been effectively removed from the workplace. It is believed that the annual incidence of asbestos reached its peak sometime between 2000 and 2005—15 to 20 years after its removal from the workplace. Nonetheless, all the recent forecasts of mesothelioma incidence extend until 2059 (if not longer)—a 75-year span from the effective end of exposure to the last projected death.

U.S. Tort System Values of a Wrongful Death Related to Exposure to Carcinogens and the EPA's "Value of a Statistical Life"

The aggregate value of the excess cancer deaths will be estimated as the product of the number of deaths appearing in the above table by the average "value" of one death. Two sources for these values will be considered—one based on the U.S. tort system and a second based on the economic concept of the "value of a statistical life" as employed by the US EPA.

The U.S. tort system value is an award arising from a jury verdict in favor of the plaintiff in a wrongful death suit. A search was done using Mealy's database for the last four years of plaintiff verdicts for asbestos-related lung cancers (17 awards) and for all benzene-related leukemias (9 awards). When inflated to 2009 dollars, the mean asbestos-related lung cancer award is $7.0 million and the mean benzene-related leukemia award is $6.0 million.

A review of how agencies of the U.S. Government value a life is provided by Robinson (2007) and among the agencies she considers in her review is the EPA. Essentially, the value of a statistical life is how much an aggregate of people are willing to spend to save one additional life per year. For example, if the 1,000,000 taxpayers in a city were willing to each pay a tax increase of $25.00 for improvements to the city's roads and it turned out that the traffic fatalities dropped from 45 before the improvements to 35 after, then that city's VSL is $(\$25\times1{,}000{,}000)/(45-35)=\$2{,}500{,}000$.

In their work on the Clean Air Act, the EPA identified 26 studies suitable for use in their analyses (Robinson, 2007, page 288). The mean of the VSLs from these studies was $4.8 million in 1990 dollars; this value becomes $7.8 million when inflated to 2009 dollars. More recently, the EPA has begun to use the results of several "meta-analyses" that combine the results of different studies in more sophisticated ways. The mean VSL from these studies is $5.5 million in 1999 dollars; inflated to 2009 dollars this becomes $7.1 million. Table 8 summarizes the U.S. tort system and EPA VSL values.

Table 8:
Mean Values of Recent Awards for Asbestos-related Lung Cancers and Benzene-related Leukemias and EPA Clean Air Act VSLs and EPA Meta-analysis VSLs

Source of the Value of a Life	*Millions of 2009 Dollars*
Mean of the Last Four Years of Plaintiff Verdict Awards for Asbestos-related Lung Cancer in Mealy's Database (17 Verdicts)	$7.0
Mean of All Plaintiff Verdict Awards for Benzene-related Leukemia in Mealy's Database (9 Verdicts)	$6.0
Mean of 26 EPA Clean Air Act Studies	$7.9
EPA Meta-Analyses	$7.1

The correspondence between all of these values is remarkable as the tort system values and EPA VSL's arise from very different sources. Because these four values are so close to each other and their average is $7.0 million, this $7.0 million average will be used to value the excess cancer deaths.

Aggregate Value of the Excess Cancer Deaths

Table 9 shows the products of the number of excess cancer deaths from 1967 until the last death (Table 7) and the mean of the four values shown in Table 8 ($7.0 million). The values shown in Table 9 are billions of 2009 dollars.

Table 9:
Aggregate Value of Excess Cancer Death Estimates by Area Defining the Exposed Population and the Last Year of Entry of Newly Exposed Persons

Last Year of Entry of Newly Exposed Persons	*Within the C.A.*	*Within 5 km*
2009	$46.9	$27.5
1990	$20.7	$12.1

References

Elandt-Johnson, R.C. & Johnson, N.L. *Survival Models and Data Analysis*. New York: John Wiley, 1980.

Hurtig, A.-K. & San Sebastian, M. Geographical differences in cancer incidence in the Amazon basin of Ecuador in relation to residence near oil fields. **International Journal of Epidemiology**, 2002, **31**, 1021-1027.

Instituto Nacional de Estadistica y Censos. *VI Censo de Poblacion y V de Vivienda 2001: Analysis Resultados Definitivos*. Author, No Date.

Instituto Nacional de Estadistica y Censos. *Estimaciones y Proyecciones de Poblacion: 1950-2025*. Author, 2003.

Instituto Nacional de Estadistica y Censos. *Proyecciones de Poblacion por Provincias, Cantones, Areas, Sexo y Grupos de Edad*. Author, 2004.

Robinson, L. How US government agencies value mortality risk reductions. **Review of Environmental Economics and Policy**, 2007, **1**, 283-299.

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QUALIFICATIONS:

Dr. Rourke has extensive experience applying advanced statistical and mathematical techniques to the solution of challenging litigation, compliance, marketing, and media problems. In addition, he has expertise in sample design and the design of large statistical database and statistical analysis systems. Dr. Rourke holds a Ph.D. in Experimental Psychology. Representative engagements include:

Quantitative Litigation Issues

- Developed actuarial/epidemiological models forecasting the volume and timing of future claims for cancers and other health problems arising from asbestos exposure for over a dozen clients. These projections are an integral part of cash flow models used to determine the rate at which assets are to be liquidated to pay injury claims. At issue is the fair and equitable distribution of funds to present and future victims of asbestos-related diseases. The amounts of these funds range from $50 million to $3.5 billion dollars, depending upon the client.

- Developed statistical models for several clients estimating settlement costs of claims for asbestos-related health problems using medical and demographic data. These models are used to estimate aggregate costs of filed but unsettled claims, to compute initial settlement offers, to monitor performance of claims negotiators, and to project costs for future claims.

- Developed statistical models for several clients estimating type, number, and aggregate value of injuries and diseases arising from workplace and environmental exposure to volatile organic compounds (e.g., benzene, toluene, cleaning agents, etc.) and to heavy metals and heavy metal compounds (e.g., lead, uranium, etc.).

- Designed and analyzed over ninety random samples used to audit patients' clinical laboratory test and expense records and consulted in their execution and presentation. The results of these samples were used to estimate reimbursements due the Federal government arising from allegedly incorrect billing for Medicare, Medicaid, and other governmentally funded medical services.

- Provided expert critical reviews of several audit samples conducted by Federal and state governmental regulatory agencies to determine monetary amounts due the agencies arising from various types of alleged under-reporting or accounting misconduct.

- Designed, managed, analyzed, and wrote reports for publication of two year–long surveys measuring the 24-hour behavior patterns of children and adults. The results of these surveys are used in conducting exposure and risk assessments to environmental toxins. The results of these surveys were published in two articles in **Risk Analysis**—the leading peer-review scientific journal in the discipline.

Marketing and Media Strategies

- Key member of the team planning, implementing, documenting, and selling the sample design for a major nation-wide system providing national TV broadcast and cable network audience estimates.

- Developed statistical models accurately forecasting personal computer sales 12 to 18 months in advance in the U.S., France, Germany, Italy, and the U.K. for a major computer maker; these models were in continuous use from 1983 to 1988 and alerted senior management to a share decline for their brand beginning in late 1984.

- Designed, coordinated, and analyzed international tracking surveys measuring personal computer penetration and purchase intentions for business, educational, and home personal computer buyers. These surveys were conducted from 1983 to 1988 in the U.S. (2,400 respondents per month) and from 1986 to 1988 in the U.K., France, Germany, and Italy (1,000 respondents per month per country).

- Developed statistical models quantifying the impact of print and broadcast advertising budgets on personal computer unit sales, revenue, and profits.

Systems Design

- Designed a database management and reporting system for the Michigan Employment Security Commission (MESC) used to maintain, retrieve, analyze, and report MESC statistical data and to help meet federal reporting and compliance standards and requirements.

EDUCATION

Ph.D. University of California, Los Angeles, 1971.
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PROFESSIONAL EXPERIENCE

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