SUPPLEMENTAL ANALYSIS: CUMULATIVE ENVIRONMENTAL IMPACTS OF SPENT NUCLEAR FUEL TRANSPORT IN THE VICINITY OF THE PROPOSED YUCCA MOUNTAIN HIGH-LEVEL WASTE REPOSITORY ATTRIBUTABLE TO LICENSE RENEWAL, AND IMPLICATIONS OF HIGHER-BURN-UP FUEL FOR THE CONCLUSIONS IN TABLE S-4

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SUPPLEMENTAL ANALYSIS: CUMULATIVE ENVIRONMENTAL IMPACTS OF SPENT NUCLEAR FUEL TRANSPORT IN THE VICINITY OF THE PROPOSED YUCCA MOUNTAIN HIGH-LEVEL WASTE REPOSITORY ATTRIBUTABLE TO LICENSE RENEWAL, AND IMPLICATIONS OF HIGHER-BURN-UP FUEL FOR THE CONCLUSIONS IN TABLE S-4

ABSTRACT

This supplemental analysis documents the staff's analysis of the potential cumulative impacts to human health of transporting spent nuclear fuel in the vicinity of the proposed Yucca Mountain high-level waste repository attributable to license renewal. This document also examines the implications of higher-burn-up fuel for the conclusions in Table S-4. The analysis shows that the cumulative radiological and accident impacts of spent nuclear fuel transport in the vicinity of the proposed repository are within the range of normally accepted risks. Because transportation is an issue that DOE will address in its EIS for the proposed repository at Yucca Mountain, mitigation is not ripe for consideration as a part of license renewal decisions. Because the values in Table S-4 and in the assessment of extended burn-up fuel are calculated as annualized reference reactor year values, they apply to the license renewal period as well as to the period of the initial operating license. The staff has extensively studied the environmental impacts associated with fuel enrichment up to 5 percent uranium-235 and fuel burn-up to 60,000 MWd/MTU and has found that these impacts are no greater than and likely less than the impacts currently in Table S-4.

INTRODUCTION

The final rule, "Environmental Review for renewal of Nuclear Power Plant Operating Licenses," which amends 10 CFR Part 51, was published in the *Federal Register* on December 18,1996 (61 FR 66537). This rule codified findings reported in NUREG-1437, "Generic Environmental Impact Statement for License Renewal of Nuclear Plants, " May 1996.

Chapter 6 of NUREG-1437, "The Uranium Fuel Cycle and Solid Waste Management" includes a review of the environmental impacts presented in Table S-4, Environmental Impact of Transportation of Fuel and Waste to and from One Light-Water-Cooled Nuclear Power Reactor, and the requirements for the use of Table S-4 given in §51.52 Environmental effects of transportation of fuel and waste—Table S-4, as applied to license renewal reviews. The data on the environmental impacts of transportation of radioactive wastes presented in Table S-4 is supplemented with analyses to extend the coverage of impacts to ^{222}Rn, ^{99}Tc, higher fuel enrichment, higher fuel burn up, and license renewal of up to 20 additional years of operation.

The Commission found that, with respect to cumulative impacts in the vicinity of the proposed repository at Yucca Mountain, Nevada and with respect to the potential impacts of higher fuel

burn up, the analysis in NUREG-1437 is not sufficiently complete to support the determination that the analysis could be adopted in each plant-specific license renewal review without further review. In the December 18, 1996 Federal Register notice (61 FR 66538) the Commission stated:

> As part of its efforts to develop regulatory guidance for this rule, the Commission will consider whether further changes to the rule are desirable to generically address: (1) The issue of cumulative transportation impacts and (2) the implications that the use of higher burn-up fuel have for the conclusions in Table S-4. After consideration of these issues, the Commission will determine whether the issue of transportation impacts should be changed to a Category 1.

This report provides the technical analyses to support such a rule change. These analyses complete the full scope of the generic analysis needed to support a determination that transportation is a Category 1 issue and that the analysis in NUREG–1437 supplemented by the information in this report and as would be codified in 10 CFR Part 51 may be adopted in each individual license renewal review.

CUMULATIVE IMPACTS OF LICENSE RENEWAL ON SPENT NUCLEAR FUEL TRANSPORT IN THE VICINITY OF THE PROPOSED YUCCA MOUNTAIN HIGH-LEVEL WASTE REPOSITORY

BACKGROUND

Renewing the operating licenses of nuclear power plants would have effect of increasing the generation of SNF during the 20-year license renewal period. This additional spent fuel would contribute the cumulative impacts of high-level waste transportation in the vicinity of the repository proposed for the Yucca Mountain site.

The Nuclear Waste Policy Act made the U.S. Department of Energy (DOE) responsible for finding a site for disposal of commercial spent nuclear fuel (SNF) and other high-level waste, and for building and operating an underground disposal facility called a geologic repository. In 1987, Congress amended the Nuclear Waste Policy Act and directed DOE to study only Yucca Mountain. Congress instructed DOE that if, at any time, Yucca Mountain were found unsuitable, studies would be stopped, the site would be restored and DOE would seek new direction from Congress.

The DOE is in the process of preparing an environmental impact statement for construction and operation of the repository. At the completion of the EIS process, and after receiving a license from NRC, it is anticipated that construction of the repository will begin. When construction has been completed, SNF and high-level waste will be shipped to the site, beginning with the oldest materials. License renewal would increase the amount of spent fuel that needs to be disposed of at the repository and the environmental effects on the

communities through which spent fuel and high-level wastes are shipped. This document addresses the cumulative environmental impacts in the vicinity of Las Vegas, Nevada.

APPROACH

The cumulative impacts of concern are the human health risks of the radiation exposures and accidents associated with SNF transport in the vicinity of Las Vegas (Clark County), Nevada. Analyses of the SNF-transport related radiation doses in the Las Vegas vicinity were performed using RADTRAN 4. Radiation exposures are reported as population dose (person-rem) and the dose to the maximally exposed individual (mrem). Health risks are reported as *expected latent cancer fatalities* (LCF, due to SNF-transport radiation exposures) and *expected fatalities* (due to highway accidents involving trucks transporting SNF, but not involving radiation releases). These terms refer to the probabilities of fatalities rather than actual fatalities. For example, 0.1 expected fatalities means that there is one-in-ten probability of a fatality.

The analysis uses the assumption that all SNF will be shipped by truck, and that the trucks will be routed on interstate highways to the maximum possible extent, as required by the U.S. Department of Transportation regulations for highway route controlled quantities of nuclear materials (49 CFR 397.101). Although rail transport of SNF is also anticipated, no analysis of rail transport was performed because rail transport would have smaller risks than truck transport (Dyer and Reich 1993).

The regulations governing allowable radiation levels during transport of radioactive materials are found at 49 CFR 173.441. Those regulations require that the external dose rate be no more than 10 mrem/hour at a distance of 2 m (6.6 ft) from the surface of the container.

To examine the effects of license renewal, the staff used two estimates of SNF that would be transported to the repository. The first estimate was based on the assumption that no nuclear plants have their licenses renewed, and the second was based on the assumption that all existing nuclear plants operate through a 20-year license renewal period. The assumption used for the second estimate is conservative because some plant owners have already decided not to renew plant operating licenses.

Per Congressional authorization, DOE is planning to accept high-level waste in the amount of 70,000 metric tons of heavy metal (MTHM, the conventional units of high-level waste) at the Yucca Mountain repository. High-level waste includes both SNF and highly radioactive materials produced by DOE. Ninety percent of this material (i.e., 63,000 MTHM) is expected to be SNF from commercial nuclear power plants. Based on this limit, DOE estimates 37,639 truck shipments of SNF to Yucca Mountain assuming all SNF travels by truck in legal-weight casks (Ken Skipper, DOE Yucca Mountain Site Office, personal communication to Donald Cleary, NRC, Rockville, Maryland, July 11, 1997). The Nuclear Waste Technical Review Board (1997) estimates that by the time the currently operating nuclear plants terminate operations (assuming no license renewal) about 85,000 MTHM of SNF will have been generated. For this analysis, the staff assumed that all current and committed SNF, about 84,000 MTHM would be disposed of at Yucca Mountain. Scaling DOE's estimated number of shipments with the amount of SNF leads to an estimate of 50,185 truck shipments without license renewal.

Assuming all plants renew their licenses and operate for an additional 20 years, the estimate increases to 75,278 truck shipments with license renewal.

Construction has begun on a beltway planned that would extend around much of Las Vegas. Two transportation route scenarios were analyzed: SNF is transported on the current freeway system, and SNF is transported on the proposed beltway.

The affected population is assumed to be those residents of Clark County, Nevada, who live within one-half mile of the route followed by the trucks transporting spent fuel. Because doses fall off quickly with distance from the route, persons close to the route receive and account for much more of the population dose than those who live away from it. The contributions to population doses contributed by exposures to persons living more than one-half mile from the route is negligible. The population density estimates were produced by the HIGHWAY computer code based on 1990 census data (Joy and Johnson 1983). Because the action would occur over 40 to 60 years, population growth in Clark County is expected. Population densities in downtown urban areas and existing suburban areas are assumed to remain constant. Population growth is assumed to manifest itself in development of the outlying areas; the population densities in the vicinity of the proposed beltway are assumed to be similar to those of other urban and suburban areas of Las Vegas.

CUMULATIVE HEALTH RISKS

Health risks associated with SNF transport include the both those associated with radiation exposures and those associated with the heavy trucks carrying SNF through the area (i.e., traffic accidents).

Radiological Risks

Radiation exposures can occur two ways: exposure to radiation emitted by the SNF cask during normal (incident-free) transport and exposures in the event of an accident that leads to release of radioactive materials.

For incident-free transportation, the staff used RADTRAN computer model to calculate total body doses to the transport crew and to the general population. The radiation source is characterized for RADTRAN by the radiation dose rate at 1 m from the package surface. The regulatory limit is 10 mrem/hour at 2 m from the container surface. The 10-mrem/hour at 1 m rate was assumed because most shipments are not expected to be close to regulatory limit, so the average does rate was assumed to be lower than the regulatory limit. The 10-mrem/hour rate at 1 m corresponds to approximately 7 mrem/hour at 2 m.[1]

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[1]10 CFR 71.47 also limits dose rate at any point on the outer surface of the package or vehicle to 200 mrem/h. Doses rates at most parts of the surface would necessarily be much lower than 200 mrem/h in order to meet the 10 mrem/h at 2 m limit. For an individual to be exposed to a dose rate this high, he would have to be in contact with the package at its most radioactive spot. For an individual to receive a significant dose he would have to lie in contact with the container at its most radioactive spot for a substantial time period. It is very unlikely that an individual would any spend time in physical contact with the package and even more unlikely that he would inadvertently choose the most radioactive spot on the package. Because such an occurrence is so unlikely, this exposure scenario is not considered relevant to analysis of cumulative impacts.

Potential accident effects include both acute fatalities due to very high radiation exposures, and latent cancer fatalities resulting from smaller radiation exposures that occur at the time of or after the hypothetical accident. Accident risk is estimated by summing the product of estimated dose and the associated probability of occurrence for each of the accident-severity categories analyzed by RADTRAN.

The expected population doses estimated by the staff (see Appendix A) are displayed in Table 1. Table 2 shows the health risks implied by the doses listed in Table 1. Examination of Table 2 shows that the probability of cancer fatalities among the public is less than 0.2 for all scenarios. The sum of incident-free and accident risks is 0.1865 LCF for the city-route-with-license-renewal scenario; other scenarios have lower estimated risks. The average annual risk is about 0.0031 LCF per year to the population of the Las Vegas area. Risks this small are too small to detect.

Table 1. Estimated cumulative radiation exposure due to SNF transport in the Las Vegas area[a]

	Radiation exposure (person-rems)		
	Incident-free transport		Transport accidents
Route scenarios	Crew[b]	Public[c]	Public
Bypass without license renewal	206.8	58.	33.8
Bypass with license renewal	310.2	87.	50.6
City route without license renewal	220.6	85.	163.
City route with license renewal	330.9	127.	246.

[a] Transportation risks were calculated using RADTRAN version 4.0.19 dated November 14, 1996.
[b] Truck crew size was assumed to be 2 persons. Crew dose is for the time spent driving approximately 170 km (~100 miles) in the Las Vegas area; the dose involved in driving to the Las Vegas area is not included.
[c] The incident-free risk to the public does not include the risk to the crew.

Table 2. Cumulative radiological transportation risks due to SNF transport in the Las Vegas area[a]

	Radiological latent cancer fatalities[b]		
	Incident-free risk		Accident risk
Route scenarios	Crew[c]	Public[d]	Public
Bypass without license renewal	0.0827	0.0290	0.0169
Bypass with license renewal	0.1241	0.0435	0.0253
City route without license renewal	0.0882	0.0425	0.0815
City route with license renewal	0.1324	0.0635	0.123

[a] Transportation risks were calculated using RADTRAN version 4.0.19 dated November 14, 1996.

[b] For crew members, the dose conversion factor was 0.0004 latent cancer fatality (LCF) per person-rem. For the public, the dose conversion factor was 0.0005 LCF per person-rem. The U.S. average lifetime risk of cancer for all causes is approximately 0.25.

[c] Truck crew size was assumed to be 2 persons. Crew risk is for the time spent driving approximately 170 km (~100 miles) in the Las Vegas area; the risk involved in driving to the Las Vegas area is not included.

[d] The incident-free risk to the public does not include the risk to the crew.

The highest estimated risk to the crews is 0.2324 LCF. These already small risks that are spread over the 40- to 60-year period during which SNF will be transported to the repository. On an annual basis, the crew risk averages about 0.0039 LCF per year of SNF transport due to radiation exposures. This risk is spread among all the truck crew members, so the risk to any one driver is extremely small.

The hypothetical maximally exposed individual would receive 31 mrem for a 60-year campaign, about 0.12 percent of the average 70-year dose from background sources.[2] The maximally exposed individual radiation dose is based on a hypothetical individual located 30 m from the highway during the entire shipment campaign (a very conservative assumption). This dose is the estimated incident-free risk from normal transport (not an accident dose).

The analysis is also conservative because it assumes that virtually all licensed nuclear power plants would operate for a 20-year license renewal term; many plants will not renew their operating licenses. Finally, if another repository were established, the already small effects on Las Vegas would be further reduced.

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[2]The background radiation dose is assumed to be 360 mrem/year, the current estimate given for average background radiation dose in the U.S. The value is based upon the following assumptions from the National Council on Radiation Protection and Measurements as summarized in Eisenbud and Gesell (1997):

Cosmic radiation that reaches the earth at sea level: 27 mrem/year
Radiation from the natural elements in the earth: 28 mrem/year
Radon gas in the home from ground sources: 200 mrem/year;
Radiation in your own body from food and water: 39 mrem/year
Average medical exposure: 25 to 55 mrem/year
Consumer products (e.g., smoke detectors): 10 mrem/year

Non-Radiological Risks

The non-radiological impact of concern is vehicle collisions. Based on recent national average truck accident rates, between 12 and 20 vehicle accidents can be expected due to SNF transport through the Las Vegas area. The probability of a fatality would be about 0.023 without license renewal and about 0.035 with license renewal (Appendix A, Table A2). These very low risk are smaller than the radiological risks of SNF transport in the Las Vegas area. Over a 40- or 60-year period, these risks amount to very small annual risks; approximately 0.0006 per year (with or without license renewal).

Conclusions

As shown in Table 2, estimated latent cancer fatalities, even under conservative assumptions, are less than one, which means that even for no member of the public or truck crew is expected to die due to radiation exposure related to SNF in the Las Vegas area. By comparison, approximately 25% of the Las Vegas population is expected to develop a fatal cancer due to causes unrelated to SNF transport. While SNF transport through Las Vegas would slightly increase the risk of cancer, the effect on public health would be immeasurable.

Non-radiological truck-vehicle accidents would be a result of transporting SNF through Las Vegas. The probability of a fatality would be less than 0.04 under all scenarios. For license renewal, the combined radiological and non-radiological risk to the public is between about 0.10 and 0.22 fatalities over the course of SNF transport through Las Vegas, including incident-free and accident risks. Without license renewal, the combined probability of a fatality is between about 0.07 and 0.15.

The above analysis shows that the cumulative radiological and accident impacts of SNF transport in the vicinity of Las Vegas, Nevada are within the range of normally accepted risks. It also shows that there are opportunities to further reduce human health impacts. Transporting SNF by rail rather than truck would reduce human health effects by reducing the number of shipments and the likelihood of accidents. Shipping SNF via the proposed beltway would reduce health impacts compared to shipping via the current interstate highway system. However, because transportation is an issue that DOE will address in its EIS for the proposed repository at Yucca Mountain, mitigation is not ripe for consideration as a part of license renewal decisions. The DOE EIS on the repository is expected to address alternative transportation modes and transportation impact mitigation measures.

IMPLICATIONS OF HIGHER BURN-UP FUEL FOR THE CONCLUSIONS IN TABLE S-4

The rule promulgated in 61 FR 66537 left license renewal applicants with the responsibility for complying with the existing requirements of 10 CFR 51.52, "Environmental effects of transportation of fuel and waste-Table S-4." Section 51.52(a) specifies six conditions that must be met in order for an applicant to adopt the values in Table S-4, which represent the contribution of transportation to the environmental costs of licensing the reactor. If the six conditions are not met, an applicant must submit a full analysis of the environmental impacts of

transportation of fuel and waste in accordance with §51.52(c). Two of the conditions limit the fuel enrichment level and the burn-up rate. Paragraph 51.52(a)(2) requires a uranium-235 enrichment not exceeding 4% by weight in the fuel. Paragraph 51.52(a)(3) requires that, "The average level of irradiation of the irradiated fuel from the reactor does not exceed 33,000 megawatt-days per metric ton, and no irradiated fuel assembly is shipped until at least 90 days after it is discharged from the reactor." Increasingly, these two limiting conditions are being exceeded through nuclear power plant license amendments permitting incremental increases in the burnup of fuel. Thus, it is likely that at the time of a submittal of a license renewal application the majority of nuclear power plants will be operating at higher fuel burnup and will be using higher enrichment fuel.

The environmental consequences of incremental increases in the burnup of fuel and the associated use of higher enrichment fuel is discusses with respect to Table S-3 and Table S-4 on pages 6-24 and 6-25 of NUREG-1437. This discussion is based on the analyses provided in NUREG/CR-5009 (PNL-6258), *Assessment of the Use of Extended Burnup Fuel in Light Water Power Reactors*, May 1988. NUREG/CR-5009 reviewed the physical effects of extended burnup on the fuel and the fuel assemblies and the associated potential for impacts during normal operation and accident events. The environmental effects were reviewed for each stage of the fuel cycle, including transportation of enriched fuel to reactors and extended burnup spent fuel from reactors. This discussion is located in the section 6.2.3 which addresses the sensitivity of values in Table S-3 and in Table S-4 to recent changes in the fuel cycle, including higher burnup fuel and the use of higher enrichment fuel. The discussion relative to Table S-4 was not repeated in the section which specifically addresses the incremental impacts of license renewal on the transportation of fuel and radioactive materials to and from nuclear power plants, section 6.3. Because of that omission, this supplemental treatment is necessary to clarify the public record as to the Commissions findings on the sensitivity of values in Table S-4 to the use of higher enrichment fuel and extended fuel burnup.

Concurrent with the publication of NUREG/CR-5009, the Commission published a notice in the *Federal Register*, "Extended Burnup Fuel Use in Commercial LWRs; Environmental Assessment and Finding of No Significant Impact" (53 FR 6040; February 29, 1988). That notice is included in Appendix B of this report. The environmental assessment was based on NUREG/CR-5009; an Atomic Industrial Forum report, AIF/NESP-032, *The Environmental Consequences of Higher Fuel Burnup*, June 1985; and NUREG/CR-2325, *The Transportation of Radioactive Material (RAM) to and from U.S. Nuclear Power Plants, December 1983*. Based on these studies, the staff concluded in the environmental assessment published at 53 FR 6040:

> ... that the environmental impacts summarized in Table S-3 of 10 CFR 51.51 and in Table S-4 of 10 CFR 51.52 for a burnup level of 33 GWd/MtU are conservative and bound the corresponding impacts for burnup levels up to 60 GWd/MtU and uranium-235 enrichments up to 5 percent by weight.

The staff further concluded that a finding of no significant impact was supported by the collective studies.

> The NRC staff has reviewed the anticipated widespread use of extended burnup fuel in commercial LWRs. Based upon the foregoing environmental assessment, the staff concluded that there are no significant adverse radiological or non-radiological impacts associated with the use of extended burnup fuel and that this use will not significantly affect the quality of the human environment.

Subsequently, the staff has continued to perform plant specific environmental assessments in reviews to raise fuel enrichment level, burnup rate, and longer fuel cycle limits in Operating Licenses and plant Technical Specifications. These assessments rely on the programmatic environmental assessment in 53 FR 6040 and on a staff assessment entitled "NRC Assessment of the Environmental Effects of Transportation Resulting From Extended Fuel Enrichment and Irradiation," which was published in the *Federal Register* on August 11, 1989 (53 FR 30355) in connection with the Shearon Harris Nuclear Power Plant, Unit 1, Environmental Assessment and Finding of No Significant Impact. That notice is included in Appendix B to this paper.

In assessing the environmental effects of transportation for 53 FR 30355, the staff reviewed the analyses in four studies and compared the findings with the impacts given in Table S-4. The studies are: (1) NUREG/CR-5009, (2) NUREG/CR-2325, (3) AIF/NESP-032, and (4) WASH-1238, *Environmental Survey of Transportation of Radioactive Materials to and from Nuclear Power Plants*, December 1972. The staff concluded:

> The above evaluation sets forth the changes resulting from increased enrichment (up to 5 weight percent) and extended irradiation (up to 60 GWd/MT), in the environmental impacts of transportation of fuel and wastes to and from the light water reactors set forth in Table S-4, 10 CFR Part 51. The values set forth in this detailed analysis represent the contribution of the environmental effects of transportation of fuel enriched with uranium 235 above 4 weight percent and up to 5 weight percent, and irradiated to levels above 33 GWd/MT and up to 60 GWd/MT to the environmental costs of operating the reactors. As shown above, the environmental cost contributions of the stated increases in fuel enrichment and irradiation limits are either unchanged or may in fact be reduced from those summarized in Table S-4, as set out in 10 CFR 51.52(c).

In 53 FR 30355, the staff further stated that, until Table S-4 is revised to include the higher fuel enrichment and irradiation levels, it proposed to accept the analysis of the environmental effects of the transportation of such fuel and waste presented in that notice.

The values in Table S-4 and in the assessment of extended burnup fuel are calculated as annualized reference reactor year values. Because these values are independent of the number of years any given reactor operates, they apply to the license renewal period as well as to the period of the initial operating license. The staff has extensively studied the environmental impacts associated with fuel enrichment up to 5 percent uranium-235 and fuel burnup to 60,000 MWd/MTU and has found that these impacts are no greater than and likely less than the impacts currently in Table S-4. The analysis in NUREG-1437 supports the staff assessment of the environmental effects of transportation resulting from extended fuel

enrichment and irradiation presented in 53 FR 30355, August 11, 1988. Therefore, these conclusions are applicable to any nuclear power plant license renewal application. Further, these conclusions provide the bases for revision of 10 CFR 51.52(a)(2) and (3).

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NUREG/CR-5009. *Assessment of the Use of Extended Burn up Fuel in Light Water Power Reactors* (PNL-6258), U.S. Nuclear Regulatory Commission, February 1988

NUREG-1437. *Generic Environmental Impact Statement for License renewal of Nuclear Plants*, U.S. Nuclear Regulatory Commission, May 1996.

WASH-1238. *Environmental Survey of Transportation of Radioactive Materials to and from Nuclear Power Plants*, U.S. Atomic Energy Commisssion, December 1972.

APPENDIX A

Cumulative Impacts from the Transportation of Spent Nuclear Fuel in the Vicinity of Las Vegas, Nevada, Associated with Nuclear Reactor License Renewal

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Introduction

The purpose of this analysis is to supplement the analysis of transportation impacts in NUREG-1437 with estimates of cumulative radiological exposure and health risk resulting from the convergence of spent nuclear fuel (SNF) shipments in the vicinity of the proposed high-level waste repository at Yucca Mountain, Nevada. The analysis addresses the impacts of transporting SNF generated by nuclear power plants during their initial license period, plus transporting SNF generated during a 20-year license renewal term. Conservative (i.e., overestimating) assumptions are used to assure that the potential impacts are not underestimated.

This study describes the transportation risk assessment performed using the HIGHWAY routing code and the RADTRAN 4 risk assessment code to determine the cumulative transportation impacts near the Las Vegas area associated with the transport of commercial spent nuclear fuel from US reactor sites to the proposed repository site at Yucca Mountain, Nevada. The study considers the effects of nuclear reactor license extension that would extend existing NRC 40 year reactor licenses up to 60 years and thus increase the amount of SNF being transported to a repository. The cumulative impacts considered were human health effects associated with both normal transport (incident-free) and with potential accidents severe enough to release radioactive material.

The focus of the analysis is on truck transportation since transport by rail would be expected to pose less risk to the general public. Rail lines tend to be located farther away from higher population densities than the comparable highway routes, rail transport allows a far greater payload and thus significantly reduces the number of shipments required, and the risk of accidents is less for rail shipments. When accident rates between truck and rail shipments are normalized for payload size and mileage, the accident rate for rail shipments is about 3% of the comparable accident rate for truck shipments (Dyer 1993).

This analysis is based on the assumption that all SNF generated by nuclear power plants is disposed of at Yucca Mountain. The U.S. Congress has authorized the proposed Yucca Mountain site to accept up to 70,000 metric tons of high-level waste. The SNF expected to be generated by the current generation of nuclear power plants is larger than the current limit for Yucca Mountain. If another repository were established to accept additional SNF, the impacts on the area around the Yucca Mountain repository would be smaller than those estimated here because some of the SNF assumed to go to Yucca Mountain would go elsewhere.

Background on the HIGHWAY Model

The HIGHWAY computer code model (Joy 1983) was used to select routes and analyze each transportation scenario. The HIGHWAY model is designed to simulate routes on the highway system in the U.S. The data base includes all interstates; most U.S. highways; and many roadways with state, county, or local classifications. It represents ~240,000 miles of roadway. Several different routing options are available in the highway program, including probable commercial routes, routes on the interstate highway system, and routes that bypass major urbanized areas. Additional detailed routing analysis can be performed by blocking individual or sets of highway segments or intersections contained in the data base.

The selection of preferred routes assumes that each shipment consists of highway route controlled quantities of radioactive materials. Travel time is optimized based on maximum utilization of the interstate highway system with preference given to bypasses around major cities, except where alternate routes have been designated by state or local officials. Selected output pages from the HIGHWAY computer code model are given in Attachment 1. These output pages supply additional information including a detailed listing of each highway route as well as mileage and population density zones.

Analysis of Routes Using the HIGHWAY Model

The total travel distance and the fraction of travel in each population density zone are needed inputs to the RADTRAN 4 code and are given in Table A1. The routing data from the HIGHWAY model, which makes use of 12 population density zones, has been collapsed into 3 zones (i.e., rural, suburban, and urban) to simplify the analysis performed by the RADTRAN code. Factors such as population density, accident rates, and vehicle speed can be varied for different zones. Each population zone, along with an associated road type, make up a RADTRAN 4 transport link.

Population density estimates for the transport routes were based on 1990 census data. The staff assumed that population growth of the Las Vegas area would occur primarily by expansion of urban and suburban areas, rather than increasing population densities. For the beltway route, population densities were assumed to be similar to those of other urban and suburban areas of Las Vegas to account for population growth induced by development of the beltway.

Table A1. Transportation route parameters used in RADTRAN analysis [a]

Roadway population density zone [b]	Las Vegas N. bypass route		Las Vegas city route	
	Distance (km)	Average population density (persons/km^2)	Distance (km)	Average population density (persons/km^2)
Rural	157.6	2.2	153.8	1.7
Suburban	8.2	357	17.7	568
Urban	0	0	5.4	2295
Total:	165.8		176.9	

[a] Based on HIGHWAY analysis, Attachment 1.
[b] Rural is defined as populations less than 139 persons/mi^2. Suburban is defined as population densities between 139 and 3326 persons/mi^2. Urban is defined as population densities greater than 3326 persons/mi^2.

The Proposed Las Vegas Beltway

This section contains background information on the proposed Las Vegas Beltway including a schematic shown in Figure 1. Information in this section was obtained from the Clark County

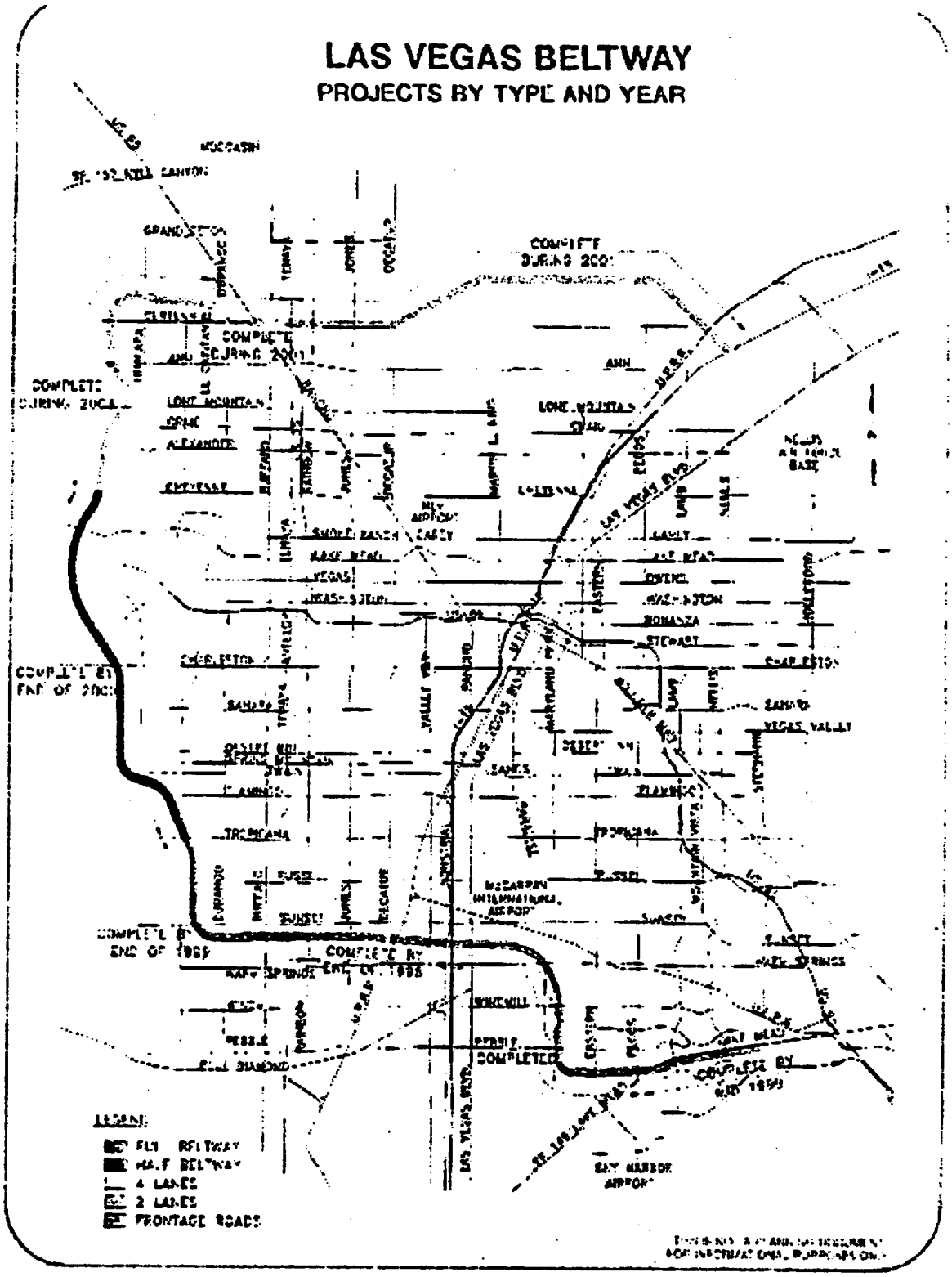

Figure 1. Proposed Las Vegas beltway. *Source*: Las Vegas Beltway, http://www.co.clark.nv.us/PUBWORKS/beltmap.jpg. Clark County Department of Public Works, accessed October 14, 1997.

Department of Public Works web page (Clark County 1997). The planned Las Vegas Beltway will eventually consist of three connected segments including a southern, western, and northern route which together will create a freeway "ring" around the Las Vegas Valley. The purpose of this facility is to take vehicles around, rather than through, the congested urban core.

The Southern Segment of the Las Vegas Beltway is being built in sections, with each segment opening to traffic upon completion. The first phase of the project, from I-15 to McCarran Airport (Airport Connector), was opened during the final days of 1994. Work on the second section of the Beltway, extending from Warm Springs Road to Windmill Lane, opened to traffic in October 1995. In February 1997, the third portion of the project stretching from Windmill Lane to Eastern Avenue became fully operational. By the fall of 1997, the fourth section of the Southern Beltway, from Eastern Avenue to Pecos Road is expected to be completed.

The proposed Northern and Western Beltway may ultimately be a ten-lane facility (a combination of mixed use and high occupancy vehicle lanes) with adequate right-of-way to permit construction of a fixed guideway facility. This is called the "ultimate facility" and will require a right-of-way width of 350 to 450 feet, plus additional land for interchanges and/or for access to other transportation facilities. The planning horizon utilized for this transportation facility is 20 years. It is anticipated that within the next 20 years, a four-lane freeway between Tropicana Avenue and Decatur Boulevard and a four-lane arterial with signalized intersections at future interchange locations will be required between Decatur Boulevard and I-15 in North Las Vegas.

Cumulative Impacts of Spent Fuel Transportation in the Las Vegas Area

This section describes the analysis of cumulative transportation impacts associated with the transport of SNF to the repository near Las Vegas, Nevada. The methodology of the risk assessment is presented along with an analysis of the transportation routes, characterization of the SNF, a description of the RADTRAN 4 computer code used to perform the radiological risk assessment, and a summary of the cumulative transportation risks.

There are 4 transportation scenarios considered in this analysis consisting of two routes, each with and without license renewal shipment volumes. The first route assumes that fuel will be shipped around the urban Las Vegas area using the proposed beltway and the second route assumes that the shipments will be routed through the center of the city using the existing interstate system.

It was assumed that with license renewal, the shipment volume of SNF would increase 50%. Without license renewal, the estimated total number of SNF shipments was 50,185. With license renewal, SNF shipments were assumed to increase to 75,278. No consideration was given to the current SNF volume limits being considered for the proposed repository site. If such volume limits were maintained, the risks calculated by this study would decrease accordingly. In addition, for the license renewal scenarios, it was assumed that there would be an increased population density along the Beltway due to future growth and expansion. The population density within the center of the city was assumed not to increase. It was assumed that growth in population density along the new Beltway would increase about 30% above 1990 census levels because there will be ample room and newly-created access routes.

SNF was assumed to be packaged in the General Atomics Corporation GA-4 and GA-9 legal-weight truck transportation casks (DOE 1990, GA 1991) because they are the only licensed spent fuel casks currently available. The radiological characteristics of the SNF were obtained from an analysis of the characteristics of potential repository wastes (DOE 1992). Table S-4 (10 CFR 51) was based on the assumption that the legal-weight truck was 73,000 lb; the current legal-weight limit is 80,000 lb. Higher legal-weight trucks allow fewer shipments and lower risks. (One of the reasons rail transport is less risky than truck transport is that smaller numbers of larger containers can be used to transport SNF.

Truck Fatalities, Injuries and Accidents

The staff estimated the number of non-radiological truck accidents that may occur during the transport of SNF to the repository. A non-radiological accident is defined as a truck accident where the injuries or fatalities are caused by only the force of the impact; no release of or exposure to radiological materials occurs due to the truck accident. This is the most common type of accident expected to occur.

Data on national accident statistics has been compiled from a number of sources by the U.S. Department of Transportation (DOT), Bureau of Transportation Statistics between 1975 and 1995. Since 1990, data has been collected on the number of accidents, injuries, and fatalities per 100 million truck-miles (DOT 1997). Based upon the accident rate data from 1990 to 1995, the average rate of large truck accidents is 233 accidents per 100 million truck-miles, the average rate of injury is 21 injuries per 100 million truck-miles, and the average fatality rate is 0.42 fatalities per 100 million truck-miles.

Using these statistics along with the HIGHWAY route data, the expected number of non-radiological accidents, injuries, and fatalities is calculated as shown in Table A2 for shipments during the 40-year (without license renewal) and 60-year (with license renewal) repository operations period.

Table A2. Truck fatalities, injuries, and accidents[a]

Route scenarios	Fatalities	Injuries	Accidents
Bypass without license renewal	0.022	1.09	12.0
Bypass with license renewal	0.033	1.63	18.1
City without license renewal	0.023	1.16	12.9
City with license renewal	0.035	1.74	19.3

[a] Accidents, injuries and fatalities are based on mileages from HIGHWAY and rates from *TABLE 3-19, Truck Fatalities, Injuries, Accidents, and Vehicle-Miles and Associated Rates by Truck Size*, U.S. Department of Transportation, Bureau of Transportation Statistics, http://www.bts.gov/programs/btsprod/nts/tbl3x19.html, accessed October 14, 1997.

Background on the RADTRAN Model

The RADTRAN 4 computer code (Neuhauser 1984, 1992) was used to model both the incident-free radiological exposure and the consequences of radiological releases due to accidents. The incident-free risks are dependent on the radiation dose rate from the shipment,

number of shipments, package dimensions, route distance, vehicle speed, and population densities along the travel routes. The accident risks are dependent on the radiological inventory, accident severity, probability of occurrence for each accident category, and the amount of inventory released, aerosolized, and inhaled, as well as the dispersibility of the waste form.

For incident-free transportation, RADTRAN calculates total body doses for the transport crew and the general population. The radiation source is characterized for RADTRAN by the radiation dose rate at 1 m from the package surface. The regulatory limit is 10 mrem/hour at 2 m from the container surface. The 10-mrem/hour at 1 m rate was assumed because most shipments are not expected to be close to regulatory limit, so the average does rate was assumed to be lower than the regulatory limit. The 10-mrem/hour rate at 1 m corresponds to approximately 7 mrem/hour at 2 m.[3]

Both point-source and line-source approximations were used based upon the distance between the exposed individuals and the radiation source. Each truck shipment of multiple fuel assemblies was modeled as a single package with a homogeneous distribution of the radiological inventory. The characteristic dimension (known in RADTRAN as the variable PKGSIZ), is the largest linear dimension of the configuration and is used in the line-source approximation to calculate total dose; 5 m (16 ft) was the assumed length of the source. Because transport casks are designed to absorb most neutron radiation and because neutron radiation is absorbed by the air in short distances, the radiation dose to the public from the casks was assumed to consist entirely of gamma radiation for calculation of the incident-free dose.

The dispersibility category is used to characterize the relative dispersibility of the radionuclide inventory based upon the chemical and physical properties of the material. RADTRAN uses the dispersibility category to determine the fractions of the total inventory that are aerosolized and respirable. RADTRAN contains default values for aerosolized and respirable fractions of the total inventory based on the assignment of dispersibility category. The user assigns a dispersibility category to each material and chooses release fractions based on the type of package as a function of accident severity.

Accident risks include both acute fatalities and latent cancer fatalities (chronic) to both the present and future generations due to accidents. The accident risk (expected value of dose from accidents) is the summation of the products of estimated dose for each accident-severity category and the associated probability of occurrence for the category.

Transportation Risk Assessment using RADTRAN 4

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[3]10 CFR 71.47 also limits dose rate at any point on the outer surface of the package or vehicle to 200 mrem/h. Doses rates at most parts of the surface would necessarily be much lower than 200 mrem/h in order to meet the 10 mrem/h at 2 m limit. For an individual to be exposed to a dose rate this high, he would have to be in contact with the package at its most radioactive spot. For an individual to receive a significant dose he would have to lie in contact with the container at its most radioactive spot for a substantial time period. It is very unlikely that an individual would any spend time in physical contact with the package and even more unlikely that he would inadvertently choose the most radioactive spot on the package. Because such an occurrence is so unlikely, this exposure scenario is not considered relevant to analysis of cumulative impacts.

The radiological health effects were estimated for two transportation routes, through Las Vegas on the current interstate system and on the proposed bypass; and for two license renewal scenarios, no license renewal (50,185 shipments) and all plants operate through one additional license renewal term (75,278 shipments). Table A3 lists the risk of latent cancer fatalities for shipments of SNF expected to result from radiation exposure during incident-free transportation and accidents. Radiation doses to the population and truck crews were converted to estimates of latent cancer fatalities (LCFs) using the upper limit risk coefficient suggested by the National Academy of Sciences (ICRP 1991, NAS 1990).

The NAS report (1990; Table 4-2), commonly called the BEIR V report, gives statistics on the number of cancer deaths expected to occur from a continuous exposure of 1 rem/year above background from age 18 until age 65. This value results in a risk factor of 4.0×10^{-4} latent cancer fatalities (LCFs) per person-rem that is most applicable to occupational exposures.

The BEIR V report also considers the number of cancer deaths expected to occur from a continuous lifetime exposure of 0.1 rem/year above background which results in a risk factor of 5.0×10^{-4} LCFs per person-rem that is most applicable to exposures of the general public. Note that even though the assumed general public exposure is less than the assumed occupational exposure, the general public LCF risk factor is slightly higher. This is because the general public dose is assumed to occur over an entire lifetime rather than just the occupational work period from age 18 until age 65. The younger population is more sensitive to radiation-induced health effects.

The results, Table A3, show that radiological risks of the truck shipments of SNF are reasonably low. The number of LCFs expected to occur from the calculated exposures would not exceed 0.1324 LCFs for the crews or 0.0635 LCFs for members of the public exposed during incident-free transportation of SNF. It was assumed that each 2 person crew would perform 1 shipment per week over the lifetime of the 40 to 60 year shipment campaign (a very conservative assumption).

The hypothetical maximally exposed individual would receive 31 mrem for the entire campaign, which is 8.6% of the 360-mrem average annual effective dose received from natural background radiation sources, or 0.12% of a 70-year dose from background sources.[4] The maximally exposed individual radiation dose is based on a hypothetical individual located 30 m from the highway during the entire shipment campaign (a very conservative assumption). A more realistic scenario would be to assume that this 31 mrem dose would be shared by dozens of shipment crews that would be required to maintain the expected shipment schedule. This dose is the estimated incident-free risk from normal transport (not an accident dose).

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[4]The background radiation dose is assumed to be 360 mrem/year, the current estimate given for average background radiation dose in the U.S. The value is based upon the following assumptions from the National Council on Radiation Protection and Measurements as summarized in Eisenbud and Gesell (1997):

Cosmic radiation that reaches the earth at sea level: 27 mrem/year
Radiation from the natural elements in the earth: 28 mrem/year
Radon gas in the home from ground sources: 200 mrem/year
Radiation in your own body from food and water: 39 mrem/year
Average medical exposure: 25 to 55 mrem/year
Consumer products (e.g., smoke detectors): 10 mrem/year

The results, Table A3, indicate that there would be no fatalities from acute radiation exposure as a result of the release of radioactive material from any of the hypothetical accidents. The largest number of LCFs associated with any of the hypothetical accident scenarios for the SNF shipments would be 0.123 LCFs. Attachment 2 provides a listing of selected pages from the RADTRAN 4 output files for each scenario including all necessary input parameters to duplicate the analysis, the incident-free summary showing the population exposure in person-rem along with the maximum individual in-transit dose, and the expected values of population risk in person-rem due to accidents.

The risk estimates listed on Table A3 must be viewed in proper perspective. While the estimated risks are low, they are higher than usually seen for SNF shipments because of the extremely high volume of shipments assumed to pass through Las Vegas. In addition, the analysis conservatively assumed that all shipments would move by truck. In reality, many shipments are expected to move by rail which would significantly reduce the risk.

The study shows that use of the Las Vegas bypass would reduce the risk to the public. The analysis is also conservative because it assumes that virtually all licensed nuclear power plants would operate for a 20-year license renewal term; many plants will not renew their operating licenses. Finally, if another repository were established, the already small effects on Las Vegas would be further reduced.

Table A3. Cumulative radiological transportation risks in the Las Vegas area [a]

	Radiological latent cancer fatalities [b]		
	Incident-free risk		Accident risk
Route scenarios	Crew [c]	Public [d]	Public
Bypass without license renewal	0.0827	0.0290	0.0169
Bypass with license renewal	0.1241	0.0435	0.0253
City without license renewal	0.0882	0.0425	0.0815
City with license renewal	0.1324	0.0635	0.123

[a] Transportation risks were calculated using RADTRAN version 4.0.19 dated November 14, 1996.

[b] For crew members, the dose conversion factor was 0.0004 latent cancer fatality (LCF) per person-rem. For the public, the dose conversion factor was 0.0005 LCF/person-rem. The U.S. average lifetime risk of cancer from all causes is approximately 0.25.

[c] Truck crew size was assumed to be 2 persons. Crew risk is for the time spent driving approximately 170 km (~100 miles) in the Las Vegas area; the risk involved in driving to the Las Vegas area is not included.

[d] The incident-free risk to the total population does not include the risk to the crew.

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Attachment 1. Listings of HIGHWAY routes examined in this study.

The following listings of the routes examined for this study have been captured from the HIGHWAY computer routing model developed at Oak Ridge National Laboratory (Joy 1983).

Route 1. From I-15 northeast of Las Vegas through the spaghetti bowl.

```
From: OVERTON        N  I15  X93  NV      Leaving : 10/02/97 at  9:14 PDT
to  : MERCURY        S  U95  LOCL NV      Arriving: 10/02/97 at 11:08 PDT

Route type: C with  2 driver(s)                      Total road time:  1:54
  Time bias:   .70  Mile bias:   .30  Toll bias:  1.00   Total miles:  110.0

The following constraints are in effect:
 1 - Links prohibiting truck use
 7 - Avoid ferry crossings
State mileage:
 NV  110.0
Mileage by highway sign type:
    Interstate:   51.0   U.S.:   59.0  State:     .0  Turnpike:     .0
       County:     .0  Local:     .0  Other:     .0
Mileage by highway lane type:
    Limited Access Multilane:   52.0  Limited Access Single Lane:     .0
          Multilane Divided:   58.0        Multilane Undivided:     .0
    Principal Highway:     .0    Through Highway:     .0   Other:     .0

From: OVERTON        N  I15  X93  NV      Leaving : 10/02/97 at  9:14 PDT
to  : MERCURY        S  U95  LOCL NV      Arriving: 10/02/97 at 11:08 PDT

  Routing through:
    .0             OVERTON        N  I15  X93  NV      .0   0:00  10/02 @  9:14
  51.0 I15         LAS VEGAS                    NV    51.0   0:47  10/02 @ 10:01
   1.0 U95         LAS VEGAS      W  U95  U95B NV    52.0   0:48  10/02 @ 10:02
   7.0 U95BU       LAS VEGAS      NW U95  U95B NV    59.0   0:59  10/02 @ 10:13
  51.0 U95         MERCURY        S  U95  LOCL NV   110.0   1:54  10/02 @ 11:08

Population Density from: OVERTON        N  I15  X93  NV
                    to : MERCURY        S  U95  LOCL NV

          ------------------ Mileage within Density Levels ------------------
                <0.0   5.0  22.7  59.7   139   326   821  1861  3326  5815
St Miles    0  -5.0 -22.7 -59.7 -139  -326  -821 -1861 -3326 -5815 -9996 >9996
-------------------------------------------------------------------------------

NV 110.0 45.7  27.3  21.9    .3    .4   1.0   2.1   4.7   3.3   2.1   1.0    .3

Totals
   110.0 45.7  27.3  21.9    .3    .4   1.0   2.1   4.7   3.3   2.1   1.0    .3
Percentages
         41.5  24.8  19.9    .2    .4    .9   1.9   4.3   3.0   2.0    .9    .2
Basis: 1990 Census
Do you want RADTRAN input data (Y/n) ?

   RADTRAN Input Data      Rural Suburban    Urban

   Weighted Population
        People/sq. mi.       4.4   1471.7   5945.2
        People/sq. km.       1.7    568.2   2295.4

   Distance                                      Total
        Miles               95.6     11.0      3.4   110.0
        Kilometers         153.8     17.7      5.4   177.0
        Percentage          86.9     10.0      3.1

   Basis (people/sq. mi.)   <139 139-3326    >3326   1990 Census

   Note: Due to rounding, the sum of the mileages in the individual
         population categories may not equal the total mileage shown
```

on this report.

Route 2. From I-15 south of Las Vegas through the spaghetti bowl.

```
From: NIPTON          W  I15  S164 CA      Leaving : 10/01/97 at 16:37 PDT
to  : MERCURY         S  U95  LOCL NV      Arriving: 10/01/97 at 18:38 PDT

Route type: Q with  2 driver(s)                        Total road time:  2:01
  Time bias:  1.00  Mile bias:   .00  Toll bias:  1.00   Total miles:  111.0

The following constraints are in effect:
 1 - Links prohibiting truck use
 6 - HM-164/State preferred routes
 7 - Avoid ferry crossings
11 - Nonintersecting Interstate Access
Weighting used with preferred highways: 10.0
State mileage:
 NV  101.0  CA   10.0
Mileage by highway sign type:
    Interstate:   52.0   U.S.:   59.0  State:     .0  Turnpike:     .0
        County:     .0  Local:     .0  Other:     .0
Mileage by highway lane type:
    Limited Access Multilane:   53.0  Limited Access Single Lane:     .0
           Multilane Divided:   58.0          Multilane Undivided:     .0
    Principal Highway:     .0    Through Highway:     .0   Other:     .0

From: NIPTON          W  I15  S164 CA      Leaving : 10/01/97 at 16:37 PDT
to  : MERCURY         S  U95  LOCL NV      Arriving: 10/01/97 at 18:38 PDT

  Routing through:
    .0               NIPTON          W  I15  S164 CA      .0   0:00  10/01 @ 16:37
  52.0 I15           LAS VEGAS                    NV     52.0   0:54  10/01 @ 17:31
   1.0 U95           LAS VEGAS       W  U95  U95B NV     53.0   0:55  10/01 @ 17:32
   7.0 U95BU         LAS VEGAS       NW U95  U95B NV     60.0   1:06  10/01 @ 17:43
  51.0 U95           MERCURY         S  U95  LOCL NV    111.0   2:01  10/01 @ 18:38

Population Density from: NIPTON          W  I15  S164 CA
                    to : MERCURY         S  U95  LOCL NV

          ------------------ Mileage within Density Levels ------------------
                <0.0   5.0  22.7  59.7   139   326   821  1861  3326  5815
St Miles     0  -5.0 -22.7 -59.7 -139  -326  -821 -1861 -3326 -5815 -9996 >9996
-------------------------------------------------------------------------------

NV 101.0 19.7  51.3  13.7   .9   1.8   3.0   2.6   4.2   2.0   1.0   1.0    .0
CA  10.0   .0  10.0    .0   .0    .0    .0    .0    .0    .0    .0    .0    .0

Totals
   111.0 19.7  61.3  13.7   .9   1.8   3.0   2.6   4.2   2.0   1.0   1.0    .0
Percentages
        17.7  55.2  12.3   .8   1.6   2.7   2.3   3.8   1.8    .9    .9    .0
Basis: 1990 Census

RADTRAN Input Data      Rural Suburban    Urban

   Weighted Population
        People/sq. mi.      5.7   1108.7   6181.1
        People/sq. km.      2.2    428.1   2386.5
   Distance                                      Total
        Miles              97.3     11.7      2.0   111.0
        Kilometers        156.6     18.9      3.2   178.6
        Percentage         87.6     10.6      1.8

   Basis (people/sq. mi.)  <139 139-3326    >3326   1990 Census
```

Note: Due to rounding, the sum of the mileages in the individual population categories may not equal the total mileage shown on this report.

Route 3. From I-15 northeast of Las Vegas using bypass.

```
From: OVERTON        N  I15  X93  NV      Leaving : 10/01/97 at 16:40 PDT
to  : MERCURY        S  U95  LOCL NV      Arriving: 10/01/97 at 18:23 PDT

Route type: C with  2 driver(s)                      Total road time:  1:43
  Time bias:   .70  Mile bias:   .30  Toll bias:  1.00   Total miles:  103.0

The following constraints are in effect:
 1 - Links prohibiting truck use
 7 - Avoid ferry crossings
State mileage:
 NV  103.0
Mileage by highway sign type:
    Interstate:   43.0   U.S.:   48.0  State:     .0  Turnpike:     .0
        County:     .0  Local:     .0  Other:   12.0
Mileage by highway lane type:
    Limited Access Multilane:   55.0  Limited Access Single Lane:     .0
          Multilane Divided:   48.0        Multilane Undivided:     .0
    Principal Highway:     .0    Through Highway:     .0   Other:     .0

From: OVERTON        N  I15  X93  NV      Leaving : 10/01/97 at 16:40 PDT
to  : MERCURY        S  U95  LOCL NV      Arriving: 10/01/97 at 18:23 PDT

  Routing through:
    .0              OVERTON        N  I15  X93  NV      .0   0:00  10/01 @ 16:40
  43.0 I15          N LAS VEGAS    N  I15  BYPS NV    43.0   0:40  10/01 @ 17:20
  12.0 BYPAS        LAS VEGAS      NW U95  BYPS NV    55.0   0:51  10/01 @ 17:31
  48.0 U95          MERCURY        S  U95  LOCL NV   103.0   1:43  10/01 @ 18:23


Population Density from: OVERTON        N  I15  X93  NV
                    to : MERCURY        S  U95  LOCL NV

          ------------------ Mileage within Density Levels ------------------
                <0.0   5.0  22.7  59.7   139   326   821  1861  3326  5815
St Miles    0  -5.0 -22.7 -59.7 -139  -326  -821 -1861 -3326 -5815 -9996 >9996
-------------------------------------------------------------------------------

NV 103.0 45.8  28.1  22.0    .2   1.8    .7   2.4   1.6    .4    .0    .0    .0

Totals
   103.0 45.8  28.1  22.0    .2   1.8    .7   2.4   1.6    .4    .0    .0    .0
Percentages
         44.5  27.3  21.4    .2   1.7    .6   2.3   1.6    .4    .0    .0    .0
Basis: 1990 Census

RADTRAN Input Data      Rural Suburban    Urban

   Weighted Population
        People/sq. mi.      5.7    924.0      .0
        People/sq. km.      2.2    356.7      .0

   Distance                                      Total
        Miles              97.9      5.1      .0   103.0
        Kilometers        157.6      8.2      .0   165.8
        Percentage         95.0      5.0      .0

   Basis (people/sq. mi.)  <139 139-3326    >3326   1990 Census

   Note: Due to rounding, the sum of the mileages in the individual population
categories may not equal the total mileage shown on this report.
```

Route 4. From I-15 south of Las Vegas using bypass.

```
From: NIPTON          W  I15  S164 CA      Leaving : 10/01/97 at 16:44 PDT
to  : MERCURY         S  U95  LOCL NV      Arriving: 10/01/97 at 18:48 PDT

Route type: C with  2 driver(s)                      Total road time: 2:04
  Time bias:   .70  Mile bias:   .30  Toll bias:  1.00   Total miles: 118.0

The following constraints are in effect:
 1 - Links prohibiting truck use
 7 - Avoid ferry crossings
State mileage:
 NV  108.0  CA   10.0
Mileage by highway sign type:
    Interstate:   44.0  U.S.:   48.0  State:     .0  Turnpike:     .0
       County:     .0  Local:     .0  Other:   26.0
Mileage by highway lane type:
    Limited Access Multilane:   70.0  Limited Access Single Lane:     .0
           Multilane Divided:   48.0          Multilane Undivided:     .0
    Principal Highway:     .0    Through Highway:     .0   Other:     .0

From: NIPTON          W  I15  S164 CA      Leaving : 10/01/97 at 16:44 PDT
to  : MERCURY         S  U95  LOCL NV      Arriving: 10/01/97 at 18:48 PDT

  Routing through:
    .0              NIPTON          W  I15  S164 CA      .0   0:00  10/01 @ 16:44
  44.0 I15          LAS VEGAS       SW I15  X34  NV    44.0   0:46  10/01 @ 17:30
  26.0 BYPAS        LAS VEGAS       NW U95  BYPS NV    70.0   1:12  10/01 @ 17:56
  48.0 U95          MERCURY         S  U95  LOCL NV   118.0   2:04  10/01 @ 18:48


Population Density from: NIPTON          W  I15  S164 CA
                    to : MERCURY         S  U95  LOCL NV

          ------------------ Mileage within Density Levels ------------------
                <0.0   5.0  22.7  59.7   139   326   821  1861  3326  5815
St Miles    0  -5.0 -22.7 -59.7 -139  -326  -821 -1861 -3326 -5815 -9996 >9996
-------------------------------------------------------------------------------

NV 108.0 20.1  50.8  13.6   4.1   4.5   4.8   5.2   4.3    .6    .0    .0    .0
CA  10.0   .0  10.0    .0    .0    .0    .0    .0    .0    .0    .0    .0    .0

Totals
   118.0 20.1  60.8  13.6   4.1   4.5   4.8   5.2   4.3    .6    .0    .0    .0
Percentages
         17.0  51.5  11.5   3.5   3.8   4.1   4.4   3.6    .5    .0    .0    .0
Basis: 1990 Census
RADTRAN Input Data       Rural Suburban    Urban

   Weighted Population
        People/sq. mi.       9.3    766.5       .0
        People/sq. km.       3.6    295.9       .0

   Distance                                      Total
        Miles              103.1     14.9       .0    118.0
        Kilometers         165.9     24.0       .0    189.9
        Percentage          87.4     12.6       .0

   Basis (people/sq. mi.)   <139 139-3326    >3326   1990 Census
```

Note: Due to rounding, the sum of the mileages in the individual population categories may not equal the total mileage shown on this report.

Attachment 2. Selected pages from the RADTRAN 4 computer code.

```
RRRR    AAA   DDDD   TTTTT  RRRR    AAA   N   N
R   R  A   A  D   D    T    R   R  A   A  NN  N
R   R  A   A  D   D    T    R   R  A   A  N N N
RRRR   A   A  D   D    T    RRRR   A   A  N  NN
R R    AAAAA  D   D    T    R R    AAAAA  N   N
R  R   A   A  D   D    T    R  R   A   A  N   N
R   R  A   A  DDDD     T    R   R  A   A  N   N
```

```
    4
4   4
4   4
44444
    4
    4
    4
```

RADTRAN 4.0.19 VERSION DATE: NOVEMBER 14, 1996

MODE DESCRIPTIONS

NUMBER	NAME	CHARACTERIZATION
1	TRUCK	LONG HAUL VEHICLE
2	RAIL	COMMERCIAL TRAIN
3	BARGE	INLAND VESSEL
4	SHIP	OPEN SEA VESSEL
5	CARGO AIR	CARGO AIRCRAFT
6	PASS AIR	PASSENGER AIRCRAFT
7	P-VAN	PASSENGER VAN
8	CVAN-T	COMMERCIAL VAN
9	CVAN-R	COMMERCIAL VAN
10	CVAN-CA	COMMERCIAL VAN

ECHO CHECK

```
&& Edited Thu Oct  2 16:57:21 1997
&& _Las_Vegas_bypass_without_license_renewal_
&& _Version_1.0_
TITLE _BYPASS_WITHOUT_RENEWAL_
FORM UNIT
DIMEN 21 8 3 10 18
PARM 1 3 2 1 0
PACKAGE
   LABGRP
        GAS       SOLID       VOLAT
SHIPMENT
   LABISO
      H3GAS        FE55        CO60        KR85        SR90       RU106
      SB125      TE125M       CS134       CS137       CE144       PM147
      SM151       EU154       EU155       PU238       PU239       PU240
      PU241       AM241       CM244
NORMAL
   NMODE=1
       8.069E-01  1.916E-01  1.500E-03  8.856E+01  4.032E+01  2.416E+01
       2.000E+00  1.000E+01  0.000E+00  0.000E+00  0.000E+00  0.000E+00
       0.000E+00  0.000E+00  2.000E+01  0.000E+00  0.000E+00  0.000E+00
       2.000E+00  1.000E-01  0.000E+00  1.000E+00  4.700E+02  7.800E+02
       2.800E+03
ACCIDENT
   SEVFRC
     NPOP=1
       NMODE=1
       4.62E-01  3.02E-01  1.76E-01  4.03E-02  1.18E-02  6.47E-03
       5.71E-04  1.13E-04
     NPOP=2
       NMODE=1
       4.35E-01  2.85E-01  2.21E-01  5.06E-02  6.64E-03  1.74E-03
       6.72E-05  5.93E-06
     NPOP=3
       NMODE=1
       5.83E-01  3.82E-01  2.78E-02  6.36E-03  7.42E-04  1.46E-04
       1.13E-05  9.94E-07
RELEASE
   RFRAC
     GROUP=1
       0.00E+00  0.00E+00  0.00E+00  1.00E-02  1.00E-01  1.10E-01
       1.10E-01  1.10E-01
     GROUP=2
       0.00E+00  0.00E+00  0.00E+00  1.00E-08  5.00E-08  5.00E-08
       5.00E-07  5.00E-07
     GROUP=3
       0.00E+00  0.00E+00  0.00E+00  1.00E-08  2.00E-04  2.80E-04
       1.00E-03  1.00E-03
EOF
ISOTOPES  -1 50185     1.00   10.000   1.00   0.00  FRRSNF
        H3GAS  9.99E+02       GAS  10
         FE55  3.64E+02     SOLID   2
         CO60  4.31E+03     SOLID   2
         KR85  1.08E+04       GAS  10
         SR90  1.30E+05     SOLID   2
        RU106  1.05E+03     VOLAT   7
        SB125  2.92E+03     SOLID   2
       TE125M  7.13E+02     SOLID   2
        CS134  1.54E+04     VOLAT   7
```

```
          CS137   1.93E+05      VOLAT    7
          CE144   2.40E+02      SOLID    2
          PM147   1.60E+04      SOLID    2
          SM151   9.07E+02      SOLID    2
          EU154   1.20E+04      SOLID    2
          EU155   4.59E+03      SOLID    2
          PU238   1.00E+04      SOLID    2
          PU239   7.30E+02      SOLID    2
          PU240   1.13E+03      SOLID    2
          PU241   1.88E+05      SOLID    2
          AM241   4.26E+03      SOLID    2
          CM244   8.29E+03      SOLID    2
LINK   1 1.58E+02 8.80E+01 2.20E+00 4.70E+02 1.37E-07 R 1
LINK   1 8.20E+00 8.80E+01 3.57E+02 7.80E+02 3.00E-06 S 1
PKGSIZ
          FRRSNF      5.00
EOF
```

_BYPASS_WITHOUT_RENEWAL_

INCIDENT-FREE SUMMARY

INCIDENT-FREE POPULATION EXPOSURE IN PERSON-REM

	PASSENGR	CREW	HANDLERS	OFF LINK	ON LINK	STOPS	STORAGE	TOTALS
LINK 1	0.00E+00	1.96E+02	0.00E+00	4.45E-01	4.97E+01	0.00E+00	0.00E+00	2.46E+02
LINK 2	0.00E+00	1.02E+01	0.00E+00	3.26E+00	4.28E+00	0.00E+00	0.00E+00	1.77E+01
RURAL	0.00E+00	1.96E+02	0.00E+00	4.45E-01	4.97E+01	0.00E+00	0.00E+00	2.46E+02
SUBURB	0.00E+00	1.02E+01	0.00E+00	3.26E+00	4.28E+00	0.00E+00	0.00E+00	1.77E+01
URBAN	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TOTALS:	0.00E+00	2.06E+02	0.00E+00	3.70E+00	5.40E+01	0.00E+00	0.00E+00	2.64E+02

MAXIMUM INDIVIDUAL IN-TRANSIT DOSE

LINK 1 2.07E-02 REM
LINK 2 2.07E-02 REM

_BYPASS_WITHOUT_RENEWAL_

EXPECTED VALUES OF POPULATION RISK IN PERSON REM

	GROUND	INHALED	RESUSPD	CLOUDSH	*INGESTION	TOTAL
LINK 1	4.43E-01	2.04E-03	8.29E-03	5.89E-06	0.00E+00	4.54E-01
LINK 2	3.25E+01	1.47E-01	5.95E-01	5.19E-04	0.00E+00	3.33E+01
RURAL	4.43E-01	2.04E-03	8.29E-03	5.89E-06	0.00E+00	4.54E-01
SUBURB	3.25E+01	1.47E-01	5.95E-01	5.19E-04	0.00E+00	3.33E+01
URBAN	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TOTALS:	3.30E+01	1.49E-01	6.03E-01	5.25E-04	0.00E+00	3.37E+01

* NOTE THAT INGESTION RISK IS A SOCIETAL RISK;
THE USER MAY WISH TO TREAT THIS VALUE SEPARATELY.

_BYPASS_WITHOUT_RENEWAL_

EXPECTED RISK VALUES - OTHER

LINK	ECON $$	EARLY FATALITY
1	0.00E+00	0.00E+00
2	0.00E+00	0.00E+00
TOTAL	0.00E+00	0.00E+00

TOTAL EXPOSED POPULATION: INCIDENT-FREE

LINK 1 5.56E+02 PERSONS
LINK 2 4.68E+03 PERSONS

TOTAL 5.24E+03 PERSONS

TOTAL EXPOSED POPULATION: ACCIDENT
(PERSONS UNDER PLUME FOOTPRINT FOR A SINGLE ACCIDENT)

LINK 1 2.97E+03 PERSONS
LINK 2 4.82E+05 PERSONS

EOI
END OF RUN

```
RRRR     AAA    DDDD    TTTTT  RRRR     AAA    N    N
R   R   A   A   D   D     T    R   R   A   A   NN   N
R   R   A   A   D   D     T    R   R   A   A   N N  N
RRRR    A   A   D   D     T    RRRR    A   A   N  N N
R R     AAAAA   D   D     T    R R     AAAAA   N   NN
R  R    A   A   D   D     T    R  R    A   A   N    N
R   R   A   A   DDDD      T    R   R   A   A   N    N
```

```
    4
4   4
4   4
44444
    4
    4
    4
```

RADTRAN 4.0.19 VERSION DATE: NOVEMBER 14, 1996

MODE DESCRIPTIONS

NUMBER	NAME	CHARACTERIZATION
1	TRUCK	LONG HAUL VEHICLE
2	RAIL	COMMERCIAL TRAIN
3	BARGE	INLAND VESSEL
4	SHIP	OPEN SEA VESSEL
5	CARGO AIR	CARGO AIRCRAFT
6	PASS AIR	PASSENGER AIRCRAFT
7	P-VAN	PASSENGER VAN
8	CVAN-T	COMMERCIAL VAN
9	CVAN-R	COMMERCIAL VAN
10	CVAN-CA	COMMERCIAL VAN

ECHO CHECK

```
&& Edited Thu Oct  2 17:16:14 1997
&& _Las_Vegas_bypass_with_license_renewal_
&& _Version_1.0_
TITLE _BYPASS_WITH_RENEWAL_
FORM UNIT
DIMEN 21 8 3 10 18
PARM 1 3 2 1 0
PACKAGE
   LABGRP
        GAS       SOLID       VOLAT
SHIPMENT
   LABISO
      H3GAS        FE55        CO60        KR85        SR90        RU106
      SB125      TE125M        CS134       CS137       CE144       PM147
      SM151       EU154        EU155       PU238       PU239       PU240
      PU241       AM241        CM244
NORMAL
   NMODE=1
       8.069E-01  1.916E-01  1.500E-03  8.856E+01  4.032E+01  2.416E+01
       2.000E+00  1.000E+01  0.000E+00  0.000E+00  0.000E+00  0.000E+00
       0.000E+00  0.000E+00  2.000E+01  0.000E+00  0.000E+00  0.000E+00
       2.000E+00  1.000E-01  0.000E+00  1.000E+00  4.700E+02  7.800E+02
       2.800E+03
ACCIDENT
   SEVFRC
     NPOP=1
       NMODE=1
       4.62E-01  3.02E-01  1.76E-01  4.03E-02  1.18E-02  6.47E-03
       5.71E-04  1.13E-04
     NPOP=2
       NMODE=1
       4.35E-01  2.85E-01  2.21E-01  5.06E-02  6.64E-03  1.74E-03
       6.72E-05  5.93E-06
     NPOP=3
       NMODE=1
       5.83E-01  3.82E-01  2.78E-02  6.36E-03  7.42E-04  1.46E-04
       1.13E-05  9.94E-07
RELEASE
   RFRAC
     GROUP=1
       0.00E+00  0.00E+00  0.00E+00  1.00E-02  1.00E-01  1.10E-01
       1.10E-01  1.10E-01
     GROUP=2
       0.00E+00  0.00E+00  0.00E+00  1.00E-08  5.00E-08  5.00E-08
       5.00E-07  5.00E-07
     GROUP=3
       0.00E+00  0.00E+00  0.00E+00  1.00E-08  2.00E-04  2.80E-04
       1.00E-03  1.00E-03
EOF
ISOTOPES  -1 75278     1.00   10.000   1.00   0.00  FRRSNF
        H3GAS  9.99E+02       GAS  10
         FE55  3.64E+02     SOLID   2
         CO60  4.31E+03     SOLID   2
         KR85  1.08E+04       GAS  10
         SR90  1.30E+05     SOLID   2
        RU106  1.05E+03     VOLAT   7
        SB125  2.92E+03     SOLID   2
       TE125M  7.13E+02     SOLID   2
        CS134  1.54E+04     VOLAT   7
        CS137  1.93E+05     VOLAT   7
        CE144  2.40E+02     SOLID   2
        PM147  1.60E+04     SOLID   2
```

```
        SM151   9.07E+02      SOLID    2
        EU154   1.20E+04      SOLID    2
        EU155   4.59E+03      SOLID    2
        PU238   1.00E+04      SOLID    2
        PU239   7.30E+02      SOLID    2
        PU240   1.13E+03      SOLID    2
        PU241   1.88E+05      SOLID    2
        AM241   4.26E+03      SOLID    2
        CM244   8.29E+03      SOLID    2
LINK  1 1.58E+02 8.80E+01 2.20E+00 4.70E+02 1.37E-07 R 1
LINK  1 8.20E+00 8.80E+01 3.57E+02 7.80E+02 3.00E-06 S 1
PKGSIZ
        FRRSNF      5.00
EOF
```

_BYPASS_WITH_RENEWAL_

INCIDENT-FREE SUMMARY
******** **** *******

INCIDENT-FREE POPULATION EXPOSURE IN PERSON-REM

	PASSENGR	CREW	HANDLERS	OFF LINK	ON LINK	STOPS	STORAGE	TOTALS
LINK 1	0.00E+00	2.94E+02	0.00E+00	6.67E-01	7.46E+01	0.00E+00	0.00E+00	3.69E+02
LINK 2	0.00E+00	1.52E+01	0.00E+00	4.89E+00	6.42E+00	0.00E+00	0.00E+00	2.66E+01
RURAL	0.00E+00	2.94E+02	0.00E+00	6.67E-01	7.46E+01	0.00E+00	0.00E+00	3.69E+02
SUBURB	0.00E+00	1.52E+01	0.00E+00	4.89E+00	6.42E+00	0.00E+00	0.00E+00	2.66E+01
URBAN	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TOTALS:	0.00E+00	3.09E+02	0.00E+00	5.55E+00	8.10E+01	0.00E+00	0.00E+00	3.96E+02

MAXIMUM INDIVIDUAL IN-TRANSIT DOSE

LINK 1 3.10E-02 REM
LINK 2 3.10E-02 REM

RUN DATE: [2-OCT-97 AT 17:16:36] PAGE 6

_BYPASS_WITH_RENEWAL_

EXPECTED VALUES OF POPULATION RISK IN PERSON REM

	GROUND	INHALED	RESUSPD	CLOUDSH	*INGESTION	TOTAL
LINK 1	6.65E-01	3.06E-03	1.24E-02	8.84E-06	0.00E+00	6.81E-01
LINK 2	4.88E+01	2.20E-01	8.92E-01	7.78E-04	0.00E+00	4.99E+01
RURAL	6.65E-01	3.06E-03	1.24E-02	8.84E-06	0.00E+00	6.81E-01
SUBURB	4.88E+01	2.20E-01	8.92E-01	7.78E-04	0.00E+00	4.99E+01
URBAN	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TOTALS:	4.95E+01	2.23E-01	9.04E-01	7.87E-04	0.00E+00	5.06E+01

* NOTE THAT INGESTION RISK IS A SOCIETAL RISK;
THE USER MAY WISH TO TREAT THIS VALUE SEPARATELY.

_BYPASS_WITH_RENEWAL_

EXPECTED RISK VALUES - OTHER

LINK	ECON $$	EARLY FATALITY
1	0.00E+00	0.00E+00
2	0.00E+00	0.00E+00
TOTAL	0.00E+00	0.00E+00

TOTAL EXPOSED POPULATION: INCIDENT-FREE

LINK 1 5.56E+02 PERSONS
LINK 2 4.68E+03 PERSONS

TOTAL 5.24E+03 PERSONS

TOTAL EXPOSED POPULATION: ACCIDENT
(PERSONS UNDER PLUME FOOTPRINT FOR A SINGLE ACCIDENT)

LINK 1 2.97E+03 PERSONS
LINK 2 4.82E+05 PERSONS

EOI
END OF RUN

```
RRRR    AAA   DDDD   TTTTT  RRRR    AAA   N   N
R   R  A   A  D   D    T    R   R  A   A  NN  N
R   R  A   A  D   D    T    R   R  A   A  N N N
RRRR   A   A  D   D    T    RRRR   A   A  N  NN
R R    AAAAA  D   D    T    R R    AAAAA  N   N
R  R   A   A  D   D    T    R  R   A   A  N   N
R   R  A   A  DDDD     T    R   R  A   A  N   N
```

```
    4
4   4
4   4
44444
    4
    4
    4
```

RADTRAN 4.0.19 VERSION DATE: NOVEMBER 14, 1996

MODE DESCRIPTIONS

NUMBER	NAME	CHARACTERIZATION
1	TRUCK	LONG HAUL VEHICLE
2	RAIL	COMMERCIAL TRAIN
3	BARGE	INLAND VESSEL
4	SHIP	OPEN SEA VESSEL
5	CARGO AIR	CARGO AIRCRAFT
6	PASS AIR	PASSENGER AIRCRAFT
7	P-VAN	PASSENGER VAN
8	CVAN-T	COMMERCIAL VAN
9	CVAN-R	COMMERCIAL VAN
10	CVAN-CA	COMMERCIAL VAN

ECHO CHECK

```
&& Edited Fri Oct  3 12:23:55 1997
&& _Las_Vegas_city_without_license_renewal_
&& _Version_1.0_
TITLE _CITY_WITHOUT_RENEWAL_
FORM UNIT
DIMEN 21 8 3 10 18
PARM 1 3 2 1 0
PACKAGE
   LABGRP
        GAS       SOLID       VOLAT
SHIPMENT
   LABISO
      H3GAS       FE55        CO60        KR85        SR90       RU106
      SB125      TE125M       CS134       CS137       CE144       PM147
      SM151       EU154       EU155       PU238       PU239       PU240
      PU241       AM241       CM244
NORMAL
   NMODE=1
       8.069E-01  1.916E-01  1.500E-03  8.856E+01  4.032E+01  2.416E+01
       2.000E+00  1.000E+01  0.000E+00  0.000E+00  0.000E+00  0.000E+00
       0.000E+00  0.000E+00  2.000E+01  0.000E+00  0.000E+00  0.000E+00
       2.000E+00  1.000E-01  0.000E+00  1.000E+00  4.700E+02  7.800E+02
       2.800E+03
ACCIDENT
   SEVFRC
     NPOP=1
       NMODE=1
       4.62E-01  3.02E-01  1.76E-01  4.03E-02  1.18E-02  6.47E-03
       5.71E-04  1.13E-04
     NPOP=2
       NMODE=1
       4.35E-01  2.85E-01  2.21E-01  5.06E-02  6.64E-03  1.74E-03
       6.72E-05  5.93E-06
     NPOP=3
       NMODE=1
       5.83E-01  3.82E-01  2.78E-02  6.36E-03  7.42E-04  1.46E-04
       1.13E-05  9.94E-07
RELEASE
   RFRAC
     GROUP=1
       0.00E+00  0.00E+00  0.00E+00  1.00E-02  1.00E-01  1.10E-01
       1.10E-01  1.10E-01
     GROUP=2
       0.00E+00  0.00E+00  0.00E+00  1.00E-08  5.00E-08  5.00E-08
       5.00E-07  5.00E-07
     GROUP=3
       0.00E+00  0.00E+00  0.00E+00  1.00E-08  2.00E-04  2.80E-04
       1.00E-03  1.00E-03
EOF
ISOTOPES  -1 50185     1.00   10.000   1.00   0.00  FRRSNF
        H3GAS  9.99E+02       GAS  10
         FE55  3.64E+02     SOLID   2
         CO60  4.31E+03     SOLID   2
         KR85  1.08E+04       GAS  10
         SR90  1.30E+05     SOLID   2
        RU106  1.05E+03     VOLAT   7
        SB125  2.92E+03     SOLID   2
```

```
        TE125M  7.13E+02      SOLID   2
         CS134  1.54E+04      VOLAT   7
         CS137  1.93E+05      VOLAT   7
         CE144  2.40E+02      SOLID   2
         PM147  1.60E+04      SOLID   2
         SM151  9.07E+02      SOLID   2
         EU154  1.20E+04      SOLID   2
         EU155  4.59E+03      SOLID   2
         PU238  1.00E+04      SOLID   2
         PU239  7.30E+02      SOLID   2
         PU240  1.13E+03      SOLID   2
         PU241  1.88E+05      SOLID   2
         AM241  4.26E+03      SOLID   2
         CM244  8.29E+03      SOLID   2
LINK  1 1.54E+02 8.80E+01 1.70E+00 4.70E+02 1.37E-07 R 1
LINK  1 1.77E+01 8.80E+01 5.68E+02 7.80E+02 3.00E-06 S 1
LINK  1 5.40E+00 7.20E+01 2.30E+03 2.80E+03 1.60E-05 U 1
PKGSIZ
         FRRSNF     5.00
EOF
```

_CITY_WITHOUT_RENEWAL_

INCIDENT-FREE SUMMARY
******** **** *******

INCIDENT-FREE POPULATION EXPOSURE IN PERSON-REM

	PASSENGR	CREW	HANDLERS	OFF LINK	ON LINK	STOPS	STORAGE	TOTALS
LINK 1	0.00E+00	1.91E+02	0.00E+00	3.35E-01	4.84E+01	0.00E+00	0.00E+00	2.40E+02
LINK 2	0.00E+00	2.19E+01	0.00E+00	1.12E+01	9.24E+00	0.00E+00	0.00E+00	4.24E+01
LINK 3	0.00E+00	8.18E+00	0.00E+00	3.49E-01	1.53E+01	0.00E+00	0.00E+00	2.38E+01
RURAL	0.00E+00	1.91E+02	0.00E+00	3.35E-01	4.84E+01	0.00E+00	0.00E+00	2.40E+02
SUBURB	0.00E+00	2.19E+01	0.00E+00	1.12E+01	9.24E+00	0.00E+00	0.00E+00	4.24E+01
URBAN	0.00E+00	8.18E+00	0.00E+00	3.49E-01	1.53E+01	0.00E+00	0.00E+00	2.38E+01
TOTALS:	0.00E+00	2.21E+02	0.00E+00	1.19E+01	7.30E+01	0.00E+00	0.00E+00	3.06E+02

MAXIMUM INDIVIDUAL IN-TRANSIT DOSE

LINK 1 2.07E-02 REM
LINK 2 2.07E-02 REM
LINK 3 2.07E-02 REM

RUN DATE: [3-OCT-97 AT 12:24:15] PAGE 6

_CITY_WITHOUT_RENEWAL_

EXPECTED VALUES OF POPULATION RISK IN PERSON REM

	GROUND	INHALED	RESUSPD	CLOUDSH	*INGESTION	TOTAL
LINK 1	3.34E-01	1.54E-03	6.24E-03	4.44E-06	0.00E+00	3.42E-01
LINK 2	1.12E+02	5.03E-01	2.04E+00	1.78E-03	0.00E+00	1.14E+02
LINK 3	4.75E+01	2.14E-01	8.68E-01	7.84E-04	0.00E+00	4.86E+01
RURAL	3.34E-01	1.54E-03	6.24E-03	4.44E-06	0.00E+00	3.42E-01
SUBURB	1.12E+02	5.03E-01	2.04E+00	1.78E-03	0.00E+00	1.14E+02
URBAN	4.75E+01	2.14E-01	8.68E-01	7.84E-04	0.00E+00	4.86E+01
TOTALS:	1.60E+02	7.19E-01	2.92E+00	2.57E-03	0.00E+00	1.63E+02

* NOTE THAT INGESTION RISK IS A SOCIETAL RISK;
THE USER MAY WISH TO TREAT THIS VALUE SEPARATELY.

_CITY_WITHOUT_RENEWAL_

EXPECTED RISK VALUES - OTHER

LINK	ECON $$	EARLY FATALITY
1	0.00E+00	0.00E+00
2	0.00E+00	0.00E+00
3	0.00E+00	0.00E+00
TOTAL	0.00E+00	0.00E+00

TOTAL EXPOSED POPULATION: INCIDENT-FREE

LINK 1 4.19E+02 PERSONS
LINK 2 1.61E+04 PERSONS
LINK 3 1.99E+04 PERSONS

TOTAL 3.64E+04 PERSONS

TOTAL EXPOSED POPULATION: ACCIDENT
(PERSONS UNDER PLUME FOOTPRINT FOR A SINGLE ACCIDENT)

LINK 1 2.30E+03 PERSONS
LINK 2 7.67E+05 PERSONS
LINK 3 3.11E+06 PERSONS

EOI
END OF RUN

```
RRRR     AAA    DDDD    TTTTT   RRRR     AAA    N   N
R   R   A   A   D   D     T     R   R   A   A   NN  N
R   R   A   A   D   D     T     R   R   A   A   N N N
RRRR    A   A   D   D     T     RRRR    A   A   N  NN
R R     AAAAA   D   D     T     R R     AAAAA   N   N
R  R    A   A   D   D     T     R  R    A   A   N   N
R   R   A   A   DDDD      T     R   R   A   A   N   N
```

```
    4
4   4
4   4
44444
    4
    4
    4
```

RADTRAN 4.0.19 VERSION DATE: NOVEMBER 14, 1996

MODE DESCRIPTIONS

NUMBER	NAME	CHARACTERIZATION
1	TRUCK	LONG HAUL VEHICLE
2	RAIL	COMMERCIAL TRAIN
3	BARGE	INLAND VESSEL
4	SHIP	OPEN SEA VESSEL
5	CARGO AIR	CARGO AIRCRAFT
6	PASS AIR	PASSENGER AIRCRAFT
7	P-VAN	PASSENGER VAN
8	CVAN-T	COMMERCIAL VAN
9	CVAN-R	COMMERCIAL VAN
10	CVAN-CA	COMMERCIAL VAN

ECHO CHECK

```
&& Edited Fri Oct  3 12:21:37 1997
&& _Las_Vegas_city_with_license_renewal_
&& _Version_1.0_
TITLE _CITY_WITH_RENEWAL_
FORM UNIT
DIMEN 21 8 3 10 18
PARM 1 3 2 1 0
PACKAGE
   LABGRP
        GAS       SOLID       VOLAT
SHIPMENT
   LABISO
      H3GAS        FE55        CO60        KR85        SR90       RU106
      SB125      TE125M       CS134       CS137       CE144       PM147
      SM151       EU154       EU155       PU238       PU239       PU240
      PU241       AM241       CM244
NORMAL
   NMODE=1
       8.069E-01  1.916E-01  1.500E-03  8.856E+01  4.032E+01  2.416E+01
       2.000E+00  1.000E+01  0.000E+00  0.000E+00  0.000E+00  0.000E+00
       0.000E+00  0.000E+00  2.000E+01  0.000E+00  0.000E+00  0.000E+00
       2.000E+00  1.000E-01  0.000E+00  1.000E+00  4.700E+02  7.800E+02
       2.800E+03
ACCIDENT
   SEVFRC
     NPOP=1
       NMODE=1
       4.62E-01  3.02E-01  1.76E-01  4.03E-02  1.18E-02  6.47E-03
       5.71E-04  1.13E-04
     NPOP=2
       NMODE=1
       4.35E-01  2.85E-01  2.21E-01  5.06E-02  6.64E-03  1.74E-03
       6.72E-05  5.93E-06
     NPOP=3
       NMODE=1
       5.83E-01  3.82E-01  2.78E-02  6.36E-03  7.42E-04  1.46E-04
       1.13E-05  9.94E-07
RELEASE
   RFRAC
     GROUP=1
       0.00E+00  0.00E+00  0.00E+00  1.00E-02  1.00E-01  1.10E-01
       1.10E-01  1.10E-01
     GROUP=2
       0.00E+00  0.00E+00  0.00E+00  1.00E-08  5.00E-08  5.00E-08
       5.00E-07  5.00E-07
     GROUP=3
       0.00E+00  0.00E+00  0.00E+00  1.00E-08  2.00E-04  2.80E-04
       1.00E-03  1.00E-03
EOF
ISOTOPES  -1 75278     1.00   10.000   1.00   0.00  FRRSNF
        H3GAS  9.99E+02       GAS  10
         FE55  3.64E+02     SOLID   2
         CO60  4.31E+03     SOLID   2
         KR85  1.08E+04       GAS  10
         SR90  1.30E+05     SOLID   2
        RU106  1.05E+03     VOLAT   7
        SB125  2.92E+03     SOLID   2
       TE125M  7.13E+02     SOLID   2
```

```
          CS134   1.54E+04      VOLAT    7
          CS137   1.93E+05      VOLAT    7
          CE144   2.40E+02      SOLID    2
          PM147   1.60E+04      SOLID    2
          SM151   9.07E+02      SOLID    2
          EU154   1.20E+04      SOLID    2
          EU155   4.59E+03      SOLID    2
          PU238   1.00E+04      SOLID    2
          PU239   7.30E+02      SOLID    2
          PU240   1.13E+03      SOLID    2
          PU241   1.88E+05      SOLID    2
          AM241   4.26E+03      SOLID    2
          CM244   8.29E+03      SOLID    2
LINK   1 1.54E+02 8.80E+01 1.70E+00 4.70E+02 1.37E-07 R 1
LINK   1 1.77E+01 8.80E+01 5.68E+02 7.80E+02 3.00E-06 S 1
LINK   1 5.40E+00 7.20E+01 2.30E+03 2.80E+03 1.60E-05 U 1
PKGSIZ
          FRRSNF      5.00
EOF
```

_CITY_WITH_RENEWAL_

INCIDENT-FREE SUMMARY
******** **** *******

INCIDENT-FREE POPULATION EXPOSURE IN PERSON-REM

	PASSENGR	CREW	HANDLERS	OFF LINK	ON LINK	STOPS	STORAGE	TOTALS
LINK 1	0.00E+00	2.86E+02	0.00E+00	5.02E-01	7.27E+01	0.00E+00	0.00E+00	3.60E+02
LINK 2	0.00E+00	3.29E+01	0.00E+00	1.68E+01	1.39E+01	0.00E+00	0.00E+00	6.36E+01
LINK 3	0.00E+00	1.23E+01	0.00E+00	5.24E-01	2.29E+01	0.00E+00	0.00E+00	3.57E+01
RURAL	0.00E+00	2.86E+02	0.00E+00	5.02E-01	7.27E+01	0.00E+00	0.00E+00	3.60E+02
SUBURB	0.00E+00	3.29E+01	0.00E+00	1.68E+01	1.39E+01	0.00E+00	0.00E+00	6.36E+01
URBAN	0.00E+00	1.23E+01	0.00E+00	5.24E-01	2.29E+01	0.00E+00	0.00E+00	3.57E+01
TOTALS:	0.00E+00	3.32E+02	0.00E+00	1.78E+01	1.09E+02	0.00E+00	0.00E+00	4.59E+02

MAXIMUM INDIVIDUAL IN-TRANSIT DOSE

LINK 1 3.10E-02 REM
LINK 2 3.10E-02 REM
LINK 3 3.10E-02 REM

EXPECTED VALUES OF POPULATION RISK IN PERSON REM

	GROUND	INHALED	RESUSPD	CLOUDSH	*INGESTION	TOTAL
LINK 1	5.01E-01	2.31E-03	9.36E-03	6.66E-06	0.00E+00	5.13E-01
LINK 2	1.68E+02	7.55E-01	3.06E+00	2.67E-03	0.00E+00	1.71E+02
LINK 3	7.12E+01	3.21E-01	1.30E+00	1.18E-03	0.00E+00	7.28E+01
RURAL	5.01E-01	2.31E-03	9.36E-03	6.66E-06	0.00E+00	5.13E-01
SUBURB	1.68E+02	7.55E-01	3.06E+00	2.67E-03	0.00E+00	1.71E+02
URBAN	7.12E+01	3.21E-01	1.30E+00	1.18E-03	0.00E+00	7.28E+01
TOTALS:	2.39E+02	1.08E+00	4.37E+00	3.85E-03	0.00E+00	2.45E+02

* NOTE THAT INGESTION RISK IS A SOCIETAL RISK;
THE USER MAY WISH TO TREAT THIS VALUE SEPARATELY.

_CITY_WITH_RENEWAL_

EXPECTED RISK VALUES - OTHER

LINK	ECON $$	EARLY FATALITY
1	0.00E+00	0.00E+00
2	0.00E+00	0.00E+00
3	0.00E+00	0.00E+00
TOTAL	0.00E+00	0.00E+00

TOTAL EXPOSED POPULATION: INCIDENT-FREE

LINK 1 4.19E+02 PERSONS
LINK 2 1.61E+04 PERSONS
LINK 3 1.99E+04 PERSONS

TOTAL 3.64E+04 PERSONS

TOTAL EXPOSED POPULATION: ACCIDENT
(PERSONS UNDER PLUME FOOTPRINT FOR A SINGLE ACCIDENT)

LINK 1 2.30E+03 PERSONS
LINK 2 7.67E+05 PERSONS
LINK 3 3.11E+06 PERSONS

EOI
END OF RUN

APPENDIX B

FEDERAL REGISTER NOTICES