Enclosure 3 to E-54423

ER Changed Pages
(Non-Proprietary)

4.2.6 Radiological Impacts of Transportation

ISP *evaluated* the radiological impacts associated with the transport of SNF to the proposed CISF site from both operating and decommissioned sites. The *evaluation* used three sample rail routes to estimate bounding doses for normal (incident-free) transportation and potential accidents for both proposed rail shipments to the CISF, and for those from the CISF to a proposed repository. Dose estimates were computed using RADTRAN *6*, a computer code originally developed by Sandia National Laboratories under contract to the Nuclear Regulatory Commission. The doses *were also calculated for a representative number of* barge and heavy haul highway shipments *for several* decommissioned sites. *Barge and heavy haul* shipments may be required to move SNF from the decommissioned site to existing rail connections. *The heavy haul and barge shipments were evaluated to see what effect they had on a route's overall dose.*

The evaluation determined that the radiological impacts for both incident-free transportation and accidents for shipments to and from the CISF were small *and well below background doses. It further showed that barge and heavy haul shipments were not major contributors to overall collective dose.*

The *population, occupational, and accident doses* were also found to be consistent with previous studies conducted by the NRC, namely:

- *Spent Nuclear Fuel Transportation Risk*, NUREG-2125 (NRC, 2014)
- *Environmental Impact Statement for the Construction and Operation of an Independent Spent Fuel Storage Installation on the Reservation for the Skull Valley Band of the Goshute Indians and the Related Transportation Facility in Tooele County, Utah* (NRC, 2001)
- *Reexamination of Spent Fuel Shipment Risk Estimates*, NUREG/CR-6672 (NRC, 2000)
- *Final Environmental Statement on the Transportation of Radioactive Material by Air and Other Modes*, NUREG-0170 (NRC, 1977)

4.2.6.1 Scope and Methodology of the *ISP Evaluation*

Radiological impacts of transporting SNF to and from the proposed CISF were estimated using RADTRAN *6* (Weiner, et al, 2014). RADTRAN *6* models both risks of routine, incident-free transportation and transportation accidents. RADTRAN was developed by SNL for the NRC to

calculate the radiological impacts of transporting radioactive materials in NUREG-0170. Since publication of NUREG-0170, RADTRAN has been updated and used to estimate the risk of radioactive material transportation for environmental impact statements and risk assessments published by NRC, the U.S. Department of Energy (DOE) and other U.S. Federal and state agencies.

The methodology used *for ISP's evaluation* is similar to those used in NUREG-2125 *to address radiological impacts.* The population densities were computed using the WebTRAGIS software. The incident-free transportation doses were calculated for populations located within 800 meters (one-half mile) along *both* sides of the transportation routes using the RADTRAN software. Incident-free doses were calculated using *a Transport Index of 14, which is consistent with* the maximum dose rate allowed for exclusive use shipments under NRC regulations (10 CFR 71.47 (b) (3)). WebTRAGIS was used in this study to determine the route length and population density along each route segment. Table 4.2-2 lists specific routing parameters used in the *evaluation. A more detailed list of parameters can be found in Table 4.1-1 of Attachment 4-1.*

Table 4.2-2, *Route Parameters for Unit Risk Calculations*

PARAMETER	*VALUE*	*SOURCE*
Unit Risk Factor - Rural	*6.11E-08*	*Calculated by RADTRAN*
Unit Risk Factor - Suburban	*5.32E-08*	*Calculated by RADTRAN*
Unit Risk Factor -Urban	*1.85E-09*	*Calculated by RADTRAN*
Rural Train Speed (km/hr.)	*40.4*	*Maximum speed limit is 80 km/hr. per Association of American Railroads Circular OT-55-P*
Suburban Train Speed (km/hr.)	*40.4*	*Assumed Lower Speed for Suburban Areas*
Urban Train Speed (km/hr.)	*24.0*	*Assumed Lower Speed for Suburban Areas*
Barge Speed (km/hr.)	*12.8*	*Used in NUREG-2125*
Heavy Haul speed (km/hr.)	*32.2*	*Used in FEIS for Yucca Mountain*
Residential Shielding Factor	*1.0*	*RADTRAN Default*
Suburban Shielding Factor	*0.87*	*RADTRAN Default*
Urban Shielding Factor	*0.018*	*RADTRAN Default*

A more detailed description of the methodology used to assess the *radiological* impacts *for* transporting SNF *to the CISF* is presented in Attachment 4-1.

Indicated changes are in response to multiple RAIs

4.2.6.2 Comparable NRC Analyses

The radiological impacts of transporting SNF have been extensively studied for nearly 40 years. Several Transportation risk studies have been published by NRC during this period of time; the most recent is *Spent Nuclear Fuel Risk Transportation, NUREG-2125 (NRC, 2014).* This study was *preceded by* Sprung, J.L., et al., *Reexamination of Spent Fuel Shipment Risk Estimates*, NUREG/CR-6672 (NRC,2000), which in turn was preceded by the *Final Environmental Statement on the Transportation of Radioactive Material by Air and Other Modes,*" NUREG-0170.(NRC, 1977).

All of the NRC's *studies mentioned above* have concluded that the risk from radiation emitted from a transportation cask during routine, incident-free transportation is a small fraction of the radiation dose received from the natural background.

NUREG 2125, *Spent Fuel Transportation Risk Assessment,* that (NRC, 2014) *concluded that*:

1. The collective dose risks from routine transportation are very small. These doses are approximately four to five orders of magnitude less than the collective background radiation dose.
2. Radioactive material would not be released in an accident if the fuel is contained in an inner welded canister inside the cask.
3. *Rail* casks without inner welded canisters *could* release radioactive material, and only then in exceptionally severe accidents.
4. If there were an accident during a spent fuel shipment, there is only about one-in-a-billion chance that the accident would result in a release of radioactive material.
5. If there were a release of radioactive material in a spent fuel shipment accident, the dose to the maximally exposed individual (MEI) would be less than 2 Sv (200 rem) and would not result in an acute lethality.
6. The collective dose risks for the two types of extremely severe accidents (accidents involving a release of radioactive material and loss of lead shielding (LOS) accidents) are negligible compared to the risk from a no-release, no-loss of shielding accident.
7. The risk of gamma shielding loss from a fire is negligible.
8. None of the fire accidents investigated in this study resulted in a release of radioactive material.

Indicated changes are in response to multiple RAIs

The NRC has also analyzed the radiological impacts from transporting SNF in several EIS's supporting other licensing actions and found the radiological impacts to be small.

In licensing the PFS SNF Storage facility, the NRC analyzed the radiological impacts associated with transporting 40,000 MTUs of SNF from Maine Yankee to Goshute Indian Reservation near Salt Lake City, Utah. The radiological impacts attributable to transportation were not significant and served as a basis for issuance of the *Environmental Impact Statement for the Construction and Operation of an Independent Spent Fuel Storage Installation on the Reservation for the Skull Valley Band of the Goshute Indians and the Related Transportation Facility in Tooele County, Utah* (NRC, 2001).

In addition, the NRC relied upon the analysis done for the PFS facility in its Generic Environmental Impact Statement (NUREG-2157) to support its recent rulemaking titled, Continued Storage of SNF (NRC, 2014a).

The NRC also analyzed the environmental impacts associated with transporting SNF from Maine Yankee to Deaf Smith County, TX, and found that the radiological impacts were not significant (NRC, 2014b, Table 2-6). *As described in Section 4.2.7.1, the doses from shipments from Maine Yankee to the CISF were the largest doses calculated for shipments to the CISF and are of the same magnitude as doses from Maine Yankee to Deaf Smith.*

4.2.7 Transportation Routes

Radiological impacts associated with transporting SNF *from 12 decommissioned reactor sites to the CISF* were analyzed*. ISP also analyzed shipments* from the CISF to the proposed repository at Yucca Mountain in Nye County, Nevada.

Since SNF *could be required* to be transported short distances by heavy haul trucks *or barge to a* rail transfer facility*, ISP analyzed a representative number of shipments to evaluate the dose effect of heavy haul and barge transport*. The transportation modes that were analyzed for the shutdown reactor sites are *shown* in Table 4.2-3. *The routes represented in Table 4.2-3 are a representative sample of routes that could be used and are not intended to include all routes that could be used for shipments to the CISF.*

Table 4.2-3, Transportation Modes from Shutdown Reactor Sites.

Site	*Transportation Modes*	
Maine Yankee	*Direct Rail*	*Barge to Rail*
Yankee Rowe		*Heavy Haul to Rail*
Connecticut Yankee	*Barge to Rail*	*Heavy Haul to Rail*
Humboldt Bay		*Barge to Rail*
Big Rock Point		*Heavy Haul to Rail*
Rancho Seco	*Direct Rail*	
Trojan	*Direct Rail*	*Barge to Rail*
La Crosse	*Direct Rail*	*Barge to Rail*
Zion	*Direct Rail*	*Barge to Rail*
Crystal River	*Direct Rail*	
Kewaunee		*Heavy Haul to Rail*
San Onofre	*Direct Rail*	

4.2.7.1 Incident Free Transportation Doses

Radiation dose calculations were performed for each *of the 12 sites listed in Table 4.2-3. The methodology used to calculate population doses is explained in Attachment 4-1. The annual collective doses for the Maine Yankee to the CISF, San Onofre to the CISF, and CISF to Yucca Mountain shipments are shown in Table 4.2-4. The annual dose represents the exposure from shipping 200 casks over a one year period. The annual doses for shipment of 200 and 655 casks per year calculated in NUREG-0170 are shown for comparison.*

The total collective dose representing the environmental impact attributable to transporting *200 casks of SNF from Maine Yankee and San Onofre to the CISF are shown in Table 4.2-5 and Table 4.2-6. The dose for shipping a single cask from the CISF to Yucca Mountain is shown in Table 4.2-7. The difference between Table 4.2-4 and Table 4.2-5/ Table 4.2-6/Table 4.2-7 are that the doses in the latter tables are broken out by state.*

The radiological impacts are *0.0873* person-Sv *(8.73* person-rem) for transporting 200 canisters of SNF each year from the Maine Yankee NPP to the CISF. The collective radiation dose for transporting 200 canisters of SNF from SONGS to the CISF each year was estimated at *0.0184* person-Sv (*1.84* person-rem). Similarly, the impacts of transporting 200 canisters from the CISF to Yucca Mountain were estimated at *0.0157* person-Sv (*1.57* person-rem). Conclusions from these transportation analyses demonstrated that the estimated *annual* collective doses along each of the three

transportation routes were *small and* comparable to those estimated in NUREG-0170 for the same number of shipments (200).

Table 4.2-4, Comparison of Annual Incident-free Transportation Impacts

Description	***Number of Rail Casks Shipped per Year***	***Collective Dose***	
		person-Sv	***person-rem***
Maine Yankee to WCS CISF	*200*	*0.0873*	*8.73*
San Onofre to WCS CISF	*200*	*0.0184*	*1.84*
WCS CISF to Yucca Mountain	*200*	*0.0157*	*1.57*
NUREG-0170	*655*	*2.90*	*290*
NUREG-0170	*200*	*0.31*	*31*

The doses calculated for San Onofre and Maine Yankee in Tables 4.2-5 and 4.2-6 assumed that all of the casks shipped in a year (200) originated at either the Maine Yankee or San Onofre site. In reality, casks shipped to the CISF in a year may originate from multiple sites; the two sites were chosen to illustrate doses that would be representative of the annual number of casks shipped to the CISF.

Table 4.2-5, *Incident-Free Radiological Transportation Impacts Maine Yankee to the CISF (200 Casks per Year)*

State	Rural		Suburban		Urban		Total	
	person-rem	person-Sv	person-rem	person-Sv	person-rem	person-Sv	person-rem	person-Sv
ME	1.72E-02	1.72E-04	3.78E-01	3.78E-03	9.60E-03	9.60E-05	4.05E-01	4.05E-03
NH	4.09E-03	4.09E-05	1.48E-01	1.48E-03	4.45E-0	4.45E-05	1.56E-01	1.56E-03
MA	5.77E-03	5.77E-05	4.59E-01	4.59E-03	3.43E-02	3.43E-04	4.99E-01	4.99E-03
CT	7.43E-03	7.43E-05	9.99E-01	9.99E-03	6.81E-02	6.81E-04	1.07E+00	1.07E-02
NY	3.96E-02	3.96E-04	5.04E-01	5.04E-03	1.56E-01	1.56E-03	7.00E-01	7.00E-03
NJ	9.21E-03	9.21E-05	4.20E-01	4.20E-03	5.16E-02	5.16E-04	4.81E-01	4.81E-03
PA	1.03E-01	1.03E-03	1.14E+00	1.14E-02	3.14E-02	3.14E-04	1.28E+00	1.28E-02
WV	1.65E-03	1.65E-05	7.11E-03	7.11E-05	0.00E+00	0.00E+00	8.76E-03	8.76E-05
OH	6.29E-02	6.29E-04	2.87E-01	2.87E-03	5.17E-03	5.17E-05	3.55E-01	3.55E-03
IN	2.96E-02	2.96E-04	5.75E-01	5.75E-03	1.02E-02	1.02E-04	6.15E-01	6.15E-03
IL	2.90E-02	2.90E-04	4.43E-01	4.43E-03	1.12E-02	1.12E-04	4.83E-01	4.83E-03
MO	5.99E-02	5.99E-04	9.00E-01	9.00E-03	7.15E-03	7.15E-05	9.67E-01	9.67E-03
KS	1.15E-02	1.15E-04	1.15E-01	1.15E-03	0.00E+00	0.00E+00	1.27E-01	1.27E-03
OK	5.92E-02	5.92E-04	8.04E-01	8.04E-03	5.17E-03	5.17E-05	8.68E-01	8.68E-03
TX	8.30E-02	8.30E-04	6.09E-01	6.09E-03	1.94E-02	1.94E-04	7.11E-01	7.11E-03
						Total	8.73E+00	8.73E-02

Indicated changes are in response to multiple RAIs

Table 4.2-6, *Incident-Free Radiological Transportation Impacts San Onofre to WCS CISF (200 Casks per Year)*

State	Rural		Suburban		Urban		Total	
	person-rem	person-Sv	person-rem	person-Sv	person-rem	person-Sv	person-rem	person-Sv
CA	2.47E-02	2.47E-04	8.73E-01	8.73E-03	9.65E-02	9.65E-04	9.94E-01	9.94E-03
AZ	4.44E-02	4.44E-04	4.88E-01	4.88E-03	5.10E-03	5.10E-05	5.38E-01	5.38E-03
NM	8.48E-03	8.48E-05	6.59E-02	6.59E-04	0.00E+00	0.00E+00	7.44E-02	7.44E-04
TX	1.42E-02	1.42E-04	2.00E-01	2.00E-03	2.11E-02	2.11E-04	2.36E-01	2.36E-03
						Total	1.84E+00	1.84E-02

Table 4.2-7, *Incident-Free Radiological Transportation Impacts WCS to Yucca Mountain (200 Casks per Year)*

State	Rural		Suburban		Urban		Total	
	person-rem	person-Sv	person-rem	person-Sv	person-rem	person-Sv	person-rem	person-Sv
TX	1.85E-02	1.85E-04	4.14E-01	4.14E-03	2.22E-02	2.22E-04	4.55E-01	4.55E-03
NM	1.68E-02	1.68E-04	1.98E-01	1.98E-03	2.54E-03	2.54E-05	2.17E-01	2.17E-03
AZ	5.00E-02	5.00E-04	7.78E-01	7.78E-03	6.10E-02	6.10E-04	8.89E-01	8.89E-03
CA	7.02E-03	7.02E-05	4.16E-03	4.16E-05	0.00E+00	0.00E+00	1.12E-02	1.12E-04
NV	3.09E-04	3.09E-06	7.41E-04	7.41E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
						Total	1.57E+00	1.57E-02

Indicated changes are in response to multiple RAIs

The doses for shipping a single cask from Maine Yankee to the WCS CISF is shown in Table 4.2-8. Maine Yankee represents the longest route that would be used during shipments to WCS CISF. Shipment of a single cask would result in a collective dose of 4.36E-4 person-Sv. This dose is small when compared to the normal background dose of 7.56 person-Sv and is consistent with the doses calculated in NUREG-2125 calculated for similar routes (e.g., the collective doses for a shipment from Maine Yankee to Deaf Smith County, Texas, NUREG-2125 in Table B-13).

Table 4.2-8, Incident-Free Radiological Transportation Impacts Maine Yankee NPP to the CISF (person-Sv)

State	Rural	Suburban	Urban	Total
CT	3.71E-07	4.99E-05	3.40E-06	5.37E-05
IL	1.45E-06	2.22E-05	5.59E-07	2.42E-05
IN	1.48E-06	2.87E-05	5.11E-07	3.07E-05
KS	5.73E-07	5.75E-06	0.00E+00	6.33E-06
MA	2.88E-07	2.29E-05	1.72E-06	2.49E-05
ME	8.59E-07	1.89E-05	4.80E-07	2.02E-05
MO	3.00E-06	4.50E-05	3.58E-07	4.83E-05
NH	2.05E-07	7.39E-06	2.22E-07	7.82E-06
NJ	4.60E-07	2.10E-05	2.58E-06	2.40E-05
NY	1.98E-06	2.52E-05	7.82E-06	3.50E-05
OH	3.15E-06	1.43E-05	2.58E-07	1.77E-05
OK	2.96E-06	4.02E-05	4.52E-07	4.36E-05
PA	5.14E-06	5.71E-05	1.57E-06	6.39E-05
TX	4.15E-06	3.04E-05	9.68E-07	3.56E-05
WV	8.27E-08	3.56E-07	0.00E+00	4.38E-07
			Total	4.36E-04

An additional *population* dose could result from the need to transport SNF *over* short distances by heavy haul truck *or barge* to a rail transfer facility. The effects of *using heavy haul or barge transport* were determined to be small. The results are summarized in Table *4.2-9* for the various shipment modes for the 12 shutdown reactor sites. *The estimates are based on three casks being transported per shipment. This over estimates the doses from heavy haul as only one cask is moved at a time.*

While all of the doses are of the same order of magnitude, the largest collective dose results for shipments from Maine Yankee. In summary, the collective doses for shipment from the sites shown in Table 4.2-9 are small. The use of barge or heavy haul transport for short segments of

the route do not significantly increase doses. The doses calculated for the twelve sites are on the same order of magnitude calculated in NUREG-2125 for similar routes.

Table 4.2-9, *Radiological Impacts from Transportation*

Transportation Impacts from 12 Shutdown Reactor Sites (Based on a single shipment of three casks)						
ORIGIN	***Population Dose (person-Sv)***			***Population Dose (person-rem)***		
	Rail	***Barge and Rail***	***Heavy Haul and Rail***	***Rail***	***Barge and Rail***	***Heavy Haul and Rail***
Maine Yankee	*1.32E-03*	*1.29E-03*		*1.32E-01*	*1.29E-01*	
Yankee Rowe			*8.85E-04*			*8.85E-02*
Connecticut Yankee		*1.09E-03*	*1.03E-03*		*1.09E-01*	*1.03E-01*
Humbolt Bay		*4.47E-04*			*4.47E-02*	
Big Rock Point			*6.74E-04*			*6.74E-02*
Rancho Seco	*4.04E-04*			*4.04E-02*		
Trojan	*6.27E-04*	*6.27E-04*		*6.27E-02*	*6.27E-02*	
La Crosse	*3.62E-04*	*8.28E-04*		*3.62E-02*	*8.28E-02*	
Zion	*4.96E-04*	*8.42E-04*		*4.96E-02*	*8.42E-02*	
Crystal River	*6.15E-04*			*6.15E-02*		
Kewaunee			*7.22E-04*			*7.22E-02*
San Onofre	*2.78E-04*			*2.78E-02*		

Indicated changes are in response to multiple RAIs

4.2.7.2 Incident Free Occupational Doses

The doses for the train crew, escorts, rail yard workers, cargo handlers, inspectors, and emergency personnel responding to an accident in which no release occurs are small and shown in Table 4.2-10.

Table 4.2-10, Occupational Doses per Shipment from Routine Incident-Free Transportation

TRAIN CREW IN TRANSIT 3 PEOPLE		DISTANCE km	TRIP DOSE Person-rem
Rural	7.78E-07	2984.18	2.32E-03
Suburban	7.78E-07	1712.18	1.33E-03
Urban	1.31E-06	346.54	4.54E-04
TOTAL			4.11E-03
RAIL YARD WORKERS		**Hours**	**Dose person-rem**
Classification Stop		27	1.65E-02
Railroad Transfer		4	2.44E-03
HANDLERS		**Hours**	**Dose person-rem**
5 PEOPLE		5	4.01E-01
ESCORTS		**Hours**	**Dose person-rem**
2 PEOPLE Escorts assumed to have 25% greater dose than crew NUREG 2125 (page B-52)		NA	3.42E-03
INSPECTORS		**Hours**	**Dose person-rem**
rem/inspection		2 meters for 4 hours	9.55E-02
FIRST RESPONDERS		**Hours**	**Dose person-rem**
person-rem/responder		3 meters for 10 hours	1.60E-01

The doses that train crews accrue during transit are determined by multiplying the unit risk factor (URF) for the crew link calculated RADTRAN by the route distance. Escorts are assumed

Indicated changes are in response to multiple RAIs

to receive 25% greater dose than crews because that have to be in line of sight to the SNF casks and have less shielding.

Doses to inspectors and first responders depend on the distance from the cask, exposure time, and number of inspectors or responders. The exposure scenarios are modelled in RADTRAN as stationary sources (train stops).

4.2.8 Impacts from Transportation Accidents

The radiological transportation impacts that could potentially occur during off-normal events were analyzed. Type B transportation casks licensed in accordance with 10 CFR Part 71 are constructed to withstand severe accidents so that most transport accidents would not result in damage to the cask body or seals that would result in a release. The *evaluation* looked at three types of potential accidents involving the transportation of SNF by rail, accidents involving no release, accidents involving a release and accidents resulting in a loss of shielding. The dose risk was found to be small for all three types of accidents, and is described in more detail in Attachment 4.1. The *conclusion* that the accident dose risk is small is consistent with previous studies conducted by the NRC.

4.2.8.1 No-Release Accident

The first type, which is the most common type of accident and typically comprises more than 99.99% of all accidents involving transportation of SNF, is an accident in which no release of radioactive material occurs. For this type of accident, the transportation cask remains intact, but members of the public along a segment of the transportation route may be exposed externally to radiation similar to exposure during routine transport of SNF. Based on experience with transporters of radioactive materials, when such an accident happens, the vehicle remains in place until either the entire vehicle or the cask can be moved. For modeling purposes, it is assumed that the transportation vehicle and cask remain in place for 10 hours.

4.2.8.2 Accident Involving the Release of Radioactive Materials

ISP evaluated severe transportation accidents that could result in the release of radioactive materials. In undertaking its evaluation, ISP assumed that the rail cask (MP197) that it modeled in RADTRAN was similar to the NAC-STC rail cask modelled in NUREG-2125. The casks have similar dimensions and are both lead shielded. ISP used the accident probabilities and release

fractions developed for the NAC-STC cask rail (NUREG-2125, Table E-16) in its RADTRAN analysis of potential releases from the MP197 cask. It is important to note that the probability and release fractions in NUREG-2125 were developed for SNF that is not contained in canisters that are welded shut. This approach is conservative for canisterized fuel because a major conclusion from NUREG-2125 is that no radioactive material would be released in an accident if the SNF is contained in an inner welded canister.

As shown in Section 5.2 of NUREG-2125, the probability of these type accidents is very small. The average accident rate for freight rail (between 1996 through 2007) was reported to be 1.10E-4 accidents per thousand rail-km (3.1E-3 accidents per thousand railcar miles) based on data from the U.S. Department of Transportation's Bureau of Transportation Statistics. Of the accidents that occur, only a small fraction could result in an impact so severe that the cask could release radioactive material. The fraction of accidents that could result in an accidental release was estimated in NUREG-2125 (Table E-16) to range from 1.13E-10 to 5.96E-12. This results in the overall probability of a release from a cask during rail transportation being of the order of 2.0E-17 (1.10E-4 x 1.13E-10).

The radioactive inventory that was used in the accident analysis is shown in Table 4.1-2 of Attachment 4-1. The radionuclides and values are based on a NUHOMS® 61BT canister containing sixty-one 7x7 BWR assemblies in the NUHOMS® MP197 shipping cask. The SNF has a burnup of 40,000 MWd/MTU, an initial average bundle enrichment of 3.3 weight percent, and is 10 year cooled. The source for this data is Table 4-1, Radionuclide Inventory, in NUHOMS® MP197 Transportation Package Safety Analysis Report, Revision 17 (TN Americas, April 2014).

ISP used RADTRAN 6 to calculate the internal and external doses to an MEI for the seven accident scenarios that NUREG-2125 determined could lead to an accidental release from a rail cask. Details on how the calculations were performed are given in Calculation Package WCS01-0506. The MEI doses are shown in Table 4.2-11.

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Table 4.2-11, MEI Doses from Accidents that Involve a Release

Cask Orientation	Seal Type	Impact Speed kph	Conditional Probability	Inhalation Sv	Re-suspension Sv	Cloud-Shine Sv	Ground-shine Sv	Total Sv
End	metal	193	5.96E-12	7.49E-02	4.10E-04	9.94E-05	1.70E-03	7.71E-02
Corner	metal	193	3.57E-11	7.49E-02	4.10E-04	9.94E-05	1.70E-03	7.71E-02
Side	elastomer	193	1.79E-11	7.49E-02	4.10E-04	9.94E-05	1.70E-03	7.71E-02
Side	metal	193	1.79E-11	7.49E-02	4.10E-04	9.94E-05	1.70E-03	7.71E-02
Side	elastomer	145	3.40E-10	7.49E-02	4.10E-04	9.94E-05	1.70E-03	7.71E-02
Side	metal	145	3.40E-10	7.49E-02	4.10E-04	9.94E-05	1.70E-03	7.71E-02
Corner	metal	145	1.13E-10	3.40E-02	1.86E-04	4.58E-05	7.67E-04	3.50E-02

The internal dose consists of the inhalation and re-suspension doses. The external dose consists of the cloud shine and ground shine doses. The doses listed in Table 4.2-11 are consequences not risks. The dose to an MEI is not the sum of the doses as each only represents one accident can happen at a time.

The conditional dose risk to the MEI, shown in Table 4.2-12, is determined by multiplying the doses by the conditional probability of the accident scenario.

Table 4.2-12, MEI Conditional Dose Risks from Accidents that Involve a Release.

Cask Orientation	Seal Type	Impact Speed kph	Conditional Probability	Inhalation Sv	Re-suspension Sv	Cloud-Shine Sv	Ground-shine Sv	Total Sv
End	metal	193	5.96E-12	4.46E-13	2.44E-15	5.92E-16	1.01E-14	4.60E-13
Corner	metal	193	3.57E-11	2.67E-12	1.46E-14	3.55E-15	6.07E-14	2.75E-12
Side	elastomer	193	1.79E-11	1.34E-12	7.34E-15	1.78E-15	3.04E-14	1.38E-12
Side	metal	193	1.79E-11	1.34E-12	7.34E-15	1.78E-15	3.04E-14	1.38E-12
Side	elastomer	145	3.40E-10	2.55E-11	1.39E-13	3.38E-14	5.78E-13	2.62E-11
Side	metal	145	3.40E-10	2.55E-11	1.39E-13	3.38E-14	5.78E-13	2.62E-11
Corner	metal	145	1.13E-10	3.84E-12	2.10E-14	5.18E-15	8.67E-14	3.95E-12

The conditional dose risk to an individual is on the order of 1E-11. It represents the risk to an individual given that an accident has already occurred. When considering the probability that an accident has occurred (1.1E-4 accidents per thousand rail-km) the overall dose risk is on the order of 1.1E-18 per km.

Collective internal and external dose risks were also calculated for a Maine Yankee to WCS Shipment. The results are shown in Tables 4.2-13 and 4.2-14.

Table 4.2-13, Maine Yankee to the CISF Collective Internal Dose Risk (person-Sv)

Population	End 193 kpm metal	Corner 193 kpm metal	Side 193 kpm elastomer	Side 193 kpm metal	Side 145 kpm elastomer	Side 145 kpm metal	Corner 145 kpm metal
Rural	2.97E-12	1.78E-11	8.93E-12	8.93E-12	1.70E-10	1.70E-10	2.56E-11
Suburban	5.09E-11	3.05E-10	1.53E-10	1.53E-10	2.90E-09	2.90E-09	4.38E-10
Urban	7.85E-11	4.71E-10	2.36E-10	2.36E-10	4.48E-09	4.48E-09	6.76E-10

Table 4.2-14 Maine Yankee to the CISF Collective External Dose Risk (person-Sv)

Population	End 193 kpm metal	Corner 193 kpm metal	Side 193 kpm elastomer	Side 193 kpm metal	Side 145 kpm elastomer	Side 145 kpm metal	Corner 145 kpm metal
Rural	7.11E-14	4.26E-13	2.13E-13	2.13E-13	4.05E-12	4.05E-12	6.09E-13
Suburban	1.22E-12	7.28E-12	3.65E-12	3.65E-12	6.94E-11	6.94E-11	1.04E-11
Urban	1.12E-11	1.12E-11	5.64E-12	5.64E-12	1.07E-10	1.07E-10	1.61E-11

The total collective dose risk for the Maine Yankee to WCS CISF is shown in Table 4.2-15. Table 4.2-15 is the sum of the internal and external dose risks in Tables 4.2-13 and 4.2-14.

Table 4.2-15, Maine Yankee to the CISF Total Collective Dose Risk (person-Sv)

Population	End 193 kpm metal	Corner 193 kpm metal	Side 193 kpm elastomer	Side 193 kpm metal	Side 145 kpm elastomer	Side 145 kpm metal	Corner 145 kpm metal
Rural	3.05E-12	1.82E-11	9.15E-12	9.15E-12	1.70E-10	1.74E-10	2.62E-11
Suburban	5.21E-11	3.12E-10	1.57E-10	1.57E-10	2.97E-09	2.97E-09	4.48E-10
Urban	8.98E-11	4.82E-10	2.42E-10	2.42E-10	4.59E-09	4.59E-09	6.92E-10

In summary, the radiological impacts of an accident that could release radioactive material are small. These accidents occur at a very low frequency. The doses to a maximum exposed individual ranged from 3.5E-2 to 7.71E-2 Sv. The conditional dose risk to an individual is on the order of 1E-11. The collective dose risk along the longest shipping route, Maine Yankee to WCS CISF, is on the order of 1E-9 to 1E-10.

4.2.8.3 Loss-of-Shielding (LOS) Accidents

ISP evaluated accidents that could result in a loss of lead shielding (LOS). The methodology that ISP used to evaluate the LOS accidents is the same as that used by the NRC in NUREG-2125, Appendix E. Two types of accidents that could cause a lead shielded cask to lose part of its shielding were analyzed. The first type of LOS accident is where a cask is involved in an accident where the cask is either in or near a hot pool fire for over three hours. At

that point the temperature of the lead exceeds its melting point and the lead begins to liquefy. When the liquid lead cools and solidifies, it occupies the same volume, but the volume available between the inner and outer cask walls is larger because of the buckling of the inner cask wall leaving a gap. The second type of accident involves severe impact where the lead shield slumps. ISP analyzed twelve accident scenarios involving LOS from severe impact.

The results of the analysis are shown in Table 4.2-16 and Table 4.2-17. The first two columns in the table represent the reduction in lead shielding and the conditional accident probability for the accident scenario analyzed. The 12 different impact scenarios represent different cask speeds and orientation during impact. A more detailed description of the accident scenarios evaluated can be found in Section E.3.1 of NUREG 2125. The conditional accident probabilities and lead lost fractions that ISP used are found in Table E-2 for impact accidents and Section E.3.1.2 for fire accidents.

Table 4.2-16 provides the estimated one hour dose to a maximum exposed individual (MEI) at specified distance for each of the LOS accidents evaluated. The dose to the MEI at 5 meters from the cask is estimated to be 8.09E-3 Sv (0.809 rem). While LOS accidents involving a fire result in the highest doses to the MEI, LOS accidents involving a severe impact have an increased probability of occurrence which result in a higher dose risk for impact accidents. The dose risks for the MEI are shown in Table 4.2-17. As an example, the largest dose risk for the MEI for a severe impact scenario is estimated to be 4.21E-13 Sv (4.21E-11 rem) for a distance of 5 meters from the cask.

NUREG-2125 calculates dose and dose risk estimates for the MEI for transportation accidents. The doses and dose risks calculated above for the MEI are small and of the same order of magnitude as those presented in NUREG-2125 in Tables E-4 and E-5 for impact accidents and Table E-8 for fire accidents.

Indicated changes are in response to multiple RAIs

Table 4.2-16, Estimated Dose for Loss of Shielding Accidents

Dose (Sv) to MEI at Various Distances from a Cask that lost Gamma Shielding due to Fire								
Reduction of Lead Shielding	Conditional Probability	1m	2m	5m	10m	20m	50m	100m
2.01E-02	3.70E-07	1.04E-02	4.68E-03	1.62E-03	1.62E-05	3.87E-06	5.86E-07	1.41E-07
8.14E-02	8.70E-15	5.23E-02	2.34E-02	8.09E-03	1.68E-04	3.85E-05	5.50E-06	1.26E-06
Dose (Sv) to MEI at Various Distances from a Cask that lost Gamma Shielding due to Impact								
Reduction of Lead Shielding	Conditional Probability	1m	2m	5m	10m	20m	50m	100m
1.84E-05	6.34E-06	1.43E-04	7.14E-05	2.85E-05	8.06E-06	2.02E-06	3.23E-07	8.06E-08
2.80E-04	1.44EE-06	2.12E-04	1.02E-04	3.92E-05	8.06E-06	2.02E-06	3.23E-07	8.06E-08
3.37E-04	6.34E-06	2.30E-04	1.10E-04	4.19E-05	8.07E-06	2.02E-06	3.23E-07	8.06E-08
1.31E-03	6.34E-06	5.73E-04	2.64E-04	9.50E-05	8.09E-06	2.02E-06	3.23E-07	8.08E-08
3.16E-03	5.96E-11	1.34E-03	6.08E-04	2.14E-04	8.22E-06	2.05E-06	3.28E-07	8.18E-08
3.73E-03	1.44E-06	1.60E-03	7.23E-04	2.53E-04	8.29E-06	2.07E-06	3.30E-07	8.23E-08
4.26E-03	1.13E-09	1.84E-03	8.31E-04	2.91E-04	8.36E-06	2.08E-06	3.32E-07	8.28E-08
5.12E-03	1.44E-06	2.25E-03	1.01E-03	3.54E-04	8.50E-06	2.12E-06	3.37E-07	8.39E-08
1.70E-02	1.13E-09	8.61E-03	3.86E-03	1.34E-03	1.37E-05	3.31E-06	5.07E-07	1.23E-07
2.34E-02	1.13E-09	1.24E-02	5.56E-03	1.93E-03	1.93E-05	4.58E-06	6.86E-07	1.64E-07
6.34E-02	5.96E-11	3.90E-02	1.75E-02	6.06E-03	1.02E-04	2.34E-05	3.36E-06	7.75E-07
7.25E-02	5.96E-11	4.57E-02	2.05E-02	7.07E-03	1.33E-04	3.05E-05	4.37E-06	1.00E-06

Indicated changes are in response to multiple RAIs

Table 4.2-17, Estimated Dose Risk for Loss of Shielding Accidents

Conditional Dose Risk (person-Sv) to MEI at Various Distances from a Cask that lost Gamma Shielding due to Fire								
Reduction of Lead Shielding	**Conditional Probability**	**1m**	**2m**	**5m**	**10m**	**20m**	**50m**	**100m**
0.0201	3.70E-07	3.85E-09	1.73E-09	5.99E-10	5.99E-12	1.43E-12	2.17E-13	5.22E-14
0.0814	8.70E-15	4.55E-16	2.04E-16	7.04E-17	1.46E-18	3.35E-19	4.79E-20	1.10E-20
Conditional Dose Risk (person-Sv) to MEI at Various Distances from a Cask that lost Gamma Shielding due to Impact								
Reduction of Lead Shielding	**Conditional Probability**	**1m**	**2m**	**5m**	**10m**	**20m**	**50m**	**100m**
1.84E-05	6.34E-06	9.07E-10	4.53E-10	1.81E-10	5.11E-11	1.28E-11	2.05E-12	5.11E-13
2.80E-04	1.44EE-06	3.05E-10	1.47E-10	5.64E-11	1.16E-11	2.91E-12	4.65E-13	1.16E-13
3.37E-04	6.34E-06	1.46E-09	6.97E-10	2.66E-10	5.12E-11	1.28E-11	2.05E-12	5.11E-13
1.31E-03	6.34E-06	3.63E-09	1.67E-09	6.02E-10	5.13E-11	1.28E-11	2.05E-12	5.12E-13
3.16E-03	5.96E-11	7.99E-14	3.62E-14	1.28E-14	4.90E-16	1.22E-16	1.95E-17	4.88E-18
3.73E-03	1.44E-06	2.30E-09	1.04E-09	3.64E-10	1.19E-11	2.98E-12	4.75E-13	1.19E-13
4.26E-03	1.13E-09	2.08E-12	9.39E-13	3.29E-13	9.45E-15	2.35E-15	3.75E-16	9.36E-17
5.12E-03	1.44E-06	3.24E-09	1.45E-09	5.10E-10	1.22E-11	3.05E-12	4.85E-13	1.21E-13
1.70E-02	1.13E-09	9.73E-12	4.36E-12	1.51E-12	1.55E-14	3.74E-15	5.73E-16	1.39E-16
2.34E-02	1.13E-09	1.40E-11	6.28E-12	2.18E-12	2.18E-14	5.18E-15	7.75E-16	1.85E-16
6.34E-02	5.96E-11	2.32E-12	1.04E-12	3.61E-13	6.08E-15	1.39E-15	2.00E-16	4.62E-17
7.25E-02	5.96E-11	2.72E-12	1.22E-12	4.21E-13	7.93E-15	1.82E-15	2.60E-16	5.96E-17

4.2.9 Nonradiological *Impacts*

ISP evaluated the *nonradiological* impacts of *rail* accidents that may occur during the transport of SNF to the *WCS CISF*. A nonradiological *impact results from a rail* accident in which the property damage, injuries, or fatalities are caused by the force of the impact; no release of or exposure to radiological materials occurs as a result of the *rail* accident. Based on the *2013* accident rate data *compiled for freight rail by the Federal Railroad Administration Office of Safety Analysis,* the average rate of injury *for freight rail was 7.1E-5 per mile (4.4E-5 per km) and the average rate of fatality was 6.0E-6 per mile (3.7E-6 per km).*

On the basis of this data, along with the WebTRAGIS computer code route data, the projected number of nonradiological injuries and fatalities for rail transport was calculated for the routes from Maine Yankee and San Onofre to the CISF and from the CISF to Yucca Mountain. The results are given in Table 4.2.18 for a single shipment, annual shipment of 200 casks in 80 shipments, and for the 40 year licensing period (3200 shipments).

Table 4.2.18, Nonradiological Impacts of Transportation

Route	Distance km	Fatalities per km	Injuries per km	Fatalities per shipment	Injuries per shipment	Fatalities per year	Injuries per year	Fatalities 40 year	Injuries 40 years
						80 shipments		3200 shipments	
Maine Yankee to WCS CISF	*5042.91*	*3.73E-07*	*4.41E-05*	*0.002*	*0.22*	*0.15*	*17.80*	*6.02*	*711.93*
Rancho Seco to WCS CISF	*1752.35*	*3.73E-07*	*4.41E-05*	*0.001*	*0.08*	*0.05*	*6.18*	*2.09*	*247.39*
WCS CISF to Yucca Mountain	*1474.69*	*3.73E-07*	*4.41E-05*	*0.001*	*0.07*	*0.04*	*5.20*	*1.76*	*208.19*

ISP also estimated the potential human health effects of vehicle emissions from locomotives during rail transport of radioactive materials.

The Final Waste Management Programmatic Environmental Impact Statement for Management, Storage and Disposal of Radioactive and Hazardous Waste, DOE/EIS-0200-F (page E-32) developed risk factors to estimate the excess latent mortality from pollution inhalation for rail shipment. The risk factor for rail shipments was 1.3E-7 per km (2.1E-7 per mile). ISP estimated the excess latent mortality based on each shipment to the CISF and later to Yucca Mountain being about 6500 km (4040 miles). This is the combined distance between Maine Yankee and the CISF and the CISF and Yucca Mountain. Assuming 3200 shipments are made during the 40 year licensing period; this would result in a distance traveled of 20.8 million km (12 million miles) and a latent mortality of 2.7. The excess latent mortality for a single shipment would be 8.45E-4.

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All indicated changes are in response to RAI TR-7

ATTACHMENT 4-1

EXPLANATION OF TRANSPORTATION ANALYSIS

This attachment has been completely replaced in response to multiple RAIs

Explanation of Transportation Analysis

Collective and occupational doses were calculated for incident-free shipments between twelve shutdown reactor sites and the WCS Consolidated Interim Storage Facility (CISF) in Andrews County, Texas, and between the CISF and Yucca Mountain using risk factor output from RADTRAN 6 together with routing and population density output from WebTRAGIS. Doses were also calculated for shipments where an accident occurs.

RADTRAN is a computer code that allows the calculation of unit risk factors (URF) for the shipment of one SNF transport cask over one kilometer through a population density of one person per square kilometer. User input parameters are used to define the characteristics of the cask, route and source terms for a shipment. The URF differs for rural, suburban and urban route segments due to differences in environmental shielding. The URF values are output in RADTRAN 6 as values for rural, suburban or urban route segments and have the units of person-rem per kilometer per person-per-square-kilometer.

WebTRAGIS is a computer code that allows determination of route length and state-level population density for rural, suburban, and urban route segments. ISP used the RADTRAN 1 mile (1.6 kilometers) transport corridor width (0.5 miles on each side of the vehicle). To calculate collective dose, the URF calculated by RADTRAN was multiplied by the length of the transport route and the population density from WebTRAGIS for rural, suburban, and urban route segments in an Excel spreadsheet. Collective doses calculated for routes between the twelve sites and the CISF and between Yucca Mountain and the CSIF were all of the same order of magnitude. The bounding collective dose was for the longest transport route, Maine Yankee Nuclear Power Plant to the WCS CISF, at approximately 4.36E-02 person-rem per shipment (8.73 person-rem for an annual shipment of 200 casks).

RADTRAN was also used to calculate occupational dose. Doses to inspectors, rail yard workers, and first responders were determined by inputting appropriate values into transport "stops" in the RADTRAN code. The main inputs for stops are distance from the source, exposure time, and number of persons exposed. Occupational dose to transport crews and escorts are determined by multiplying the URF for the crews by the route distance and number of persons. Escorts are assumed to have a 25% higher dose than crew because they have to be in line of sight to the SNF and have less shielding. Occupational doses calculated during incident-free shipment for the twelve sites to Yucca Mountain are small and remain bounded by the collective dose for the longest transport route, Maine Yankee Nuclear Power Plant to the WCS CISF.

Accidents with no release resulted in doses that are small, with first responders being the maximally-exposed individual (MEI) receiving an occupational dose of 1.60E-01 rem after 10 hours at 3 meters (see Table 4.2-10 of Section 4.2.7.2). Accidents with loss of shielding (LOS) resulted in a dose to the MEI of 8.1E-3 Sv (0.81 rem) per hour at 5 meters (LOS due to fire), or 7.1E-3 Sv (0.71 rem) per hour at 5 meters (LOS due to impact). Accidents with release result in an occupational dose to the MEI of 7.71 rem after 1 day within 33 meters. LOS Accident doses are included in Table 4.2-16 of Section 4.2.8.3.

For accidents with release, collective doses were also calculated. The internal collective dose was calculated by multiplying the transport accident rate, cask damage conditional probability, route length, population density, plume area of release and the sum of the internal doses (inhalation and re-suspension). The external collective dose was calculated by multiplying the

transport accident rate, cask damage conditional probability, route length, population density, plume area of release and the sum of the external doses (cloud-shine and ground-shine). Release parameters were taken for casks sealed with elastomeric or metal O-rings with uncanisterized SNF, which is a very conservative approach for shipments of canisterized SNF since NUREG-2125 concluded that there would be no release from such casks.

The RADTRAN input parameters used in calculating the URF are shown in Table 4.1-1 with the exception of the radionuclide inventory values used in transportation accident release calculations which are included in Table 4.1-2. As described in Section 4.2.8.2 the radionuclides and values are based on a NUHOMS® 61BT canister containing sixty-one 7x7 BWR assemblies in the NUHOMS® MP197 shipping cask. The SNF has a burnup of 40,000 MWd/MTU, an initial average bundle enrichment of 3.3 weight percent and is 10 year cooled.

The pertinent portions of the spreadsheets for calculating collective doses for a single shipment are included in Table 4.1-3. The spreadsheets, and results in Table 4.1-3 include the following representative routes and modes of transport:

1. Maine Yankee
    a. Maine Yankee to Portland ME (Barge)
    b. Portland ME to Monahans TX (Rail)
    c. Maine Yankee to Monahan's TX (Rail)
2. Yankee Rowe
    a. Yankee Rowe to Albany NY (Heavy Haul Truck)
    b. Albany NY to Monahans TX (Rail)
    c. Yankee Rowe to Monahans TX (Rail)
3. Connecticut Yankee
    a. Haddam Neck to Middletown Junction (Heavy Haul Truck)
    b. Middletown Junction to Monahans TX (Rail)
    c. Haddam Neck to New Haven CT (Barge)
    d. New Haven CT to Monahans TX (Rail)
4. Humboldt Bay
    a. Humboldt Bay to San Francisco, CA (Barge)
    b. San Francisco, CA to Monahans TX (Rail)
5. Big Rock Point
    a. Big Rock Point to Cadillac MI (Heavy Haul Truck)
    b. Cadillac MI to Monahans TX (Rail)
6. Rancho Seco
    a. Rancho Seco to Monahans TX (Rail)
7. Trojan
    a. Trojan to Monahans TX (Rail)

   b. Trojan to Willamette River, Portland OR (Barge)
   c. Willamette River, Portland OR to Monahans TX (Rail)

8. LaCrosse
   a. LaCrosse to Monahans TX (Rail)
   b. LaCrosse to Genoa WI (Barge)
   c. Genoa WI to Monahans TX (Rail)
9. Zion
   a. Zion to Monahans TX (Rail)
   b. Zion to Rock Island-Davenport (Barge)
   c. Rock Island-Davenport to Monahans TX (Rail)
10. Crystal River
    a. Crystal River to Monahans TX (Rail)
11. Kewaunee
    a. Kewaunee to Green Bay, WI (Heavy Haul Truck)
    b. Green Bay, WI to Monahans TX (Rail)
12. San Onofre
    a. San Onofre to Monahans TX (Rail)
13. WCS to Yucca Mountain

Occupational dose for accidents during SNF transport for the twelve shutdown reactor sites plus Yucca Mountain were also calculated using RADTRAN and WebTRAGIS, with the MEI being the bounding individual for occupational dose. Accidents with no releases, accidents with loss of shielding (LOS, resulting from impact or fire), and accidents with releases were considered. Table 4.1-4 is a copy of the pertinent portion of the spreadsheet used to assess occupational doses from routine, incident-free transportation of SNF on a per shipment basis.

Table 4.1-1
Input Parameters for RADTRAN 6
(2 pages)

Package-Specific Parameters		
PARAMETER	VALUE	SOURCE
Dose Rate at 1 meter (mrem/hr.)	14.00	Estimate based on dose limit of two meters from package surface of 10 mrem/hr.
Gamma fraction	0.41	Table A.5-1, MP197 Transportation Safety Analysis Report, Rev.14.
Neutron Fraction	0.59	MP197 Transportation Safety Analysis Report, Rev.14.
Length (Longest Dimension in meters)	5.28	NRC Certificate of Compliance No. 9302; Cask Length

Vehicle-Specific Parameters		
PARAMETER	VALUE	SOURCE
Exclusive Use	Yes	NRC Certificate of Compliance No. 9302
Transportation Mode	Rail	NRC Certificate of Compliance No. 9302
Dose Rate at 1 meter (mrem/hr.)	14.00	Estimate based on dose limit of two meters from vehicle (package) surface of 10 mrem/hr.
Gamma fraction	0.41	See above
Neutron Fraction	0.59	See above
Length	5.28	NRC Certificate of Compliance No. 9302; Same as Cask Length
Number of shipments	1	Unit Risk Factor (one shipment travelling one kilometer past a population density of one person per square kilometer)
Number of crew	3	NUREG-2125, Page B-38
Distance of crew to cask (m)	150	Data Entry for RADTRAN in NUREG-2125, Figure B-6
Crew Shielding Factor	1	Data Entry for RADTRAN in NUREG-2125, Figure B-6; accounts for shielding in rail cars.
Crew View Dimension (m)	2.30	NRC Certificate of Compliance No. 9302; Cask Diameter
Number of casks per railcar	1	Unit Risk Factor (one shipment travelling one kilometer past a population density of one person per square kilometer)

This attachment has been completely replaced in response to multiple RAIs

Table 4.1-1
Input Parameters for RADTRAN 6
(Continued)

Route Parameters for Unit Risk Calculations		
PARAMETER	VALUE	SOURCE
Rural vehicle speed (km/hr.)	40.4	Maximum speed limit is 80 km/hr. per Association of American Railroads Circular OT-55-P
Suburban vehicle speed (km/hr.)	40.4	Assumed Lower Speed for Suburban Areas
Urban vehicle speed (km/hr.)	24.0	Assumed Lower Speed for Urban Areas
Barge Speed (km/hr.)	12.8	Used in NUREG-2125
Heavy Haul speed (km/hr.)	32.2	Used in FEIS for Yucca Mountain
Rural vehicle density (railcars/hr.)	17	NUREG-2125, Table B-2
Suburban vehicle density (railcars/hr.)	17	NUREG-2125, Table B-2
Urban vehicle density (railcars/hr.)	17	NUREG-2125, Table B-2
Persons (Crew) per vehicle	3	NUREG-2125, Page B-38
Farm Fraction (rural)	0.5	NUREG-2125, Table B-2
Farm Fraction (suburban)	0.0	Data Entry for RADTRAN in NUREG-2125, Figure B-6
Farm Fraction (urban)	0.0	Data Entry for RADTRAN in NUREG-2125, Figure B-6
Minimum distance of stop from nearby residents (m)	200	NUREG-2125, Table 2-10
Maximum distance of stop from nearby residents (m)	800	NUREG-2125, Table 2-10
Stop time for classification (hours)	27	NUREG-2125, Table 2-10
Stop time in transit for railroad change (hours)	4	NUREG-2125, Table 2-10
Escort Distance from Cask (m)	16	NUREG-2125, Table B-2

Accident Parameters used in RADTRAN		
Train Accident Rate (accidents/km)	1.1E-07	NUREG-2125, Section 5.2
Accident Severities (Conditional Probabilities) and Release Fractions	Various	NUREG-2125, Table E-16 Note: Release fractions equal rod to cask release fraction times cask to environment release fraction.
Loss of Shielding Parameters	Various	NUREG-2125, Table E-2

This attachment has been completely replaced in response to multiple RAIs

Table 4.1-2
Radionuclide Inventory used in Transportation Accident release Calculations

Radionuclide	Curies	TBq	Physical Group
H-3	3.90E+03	1.44E+02	GAS
KR-85	1.03E+03	3.81E+01	GAS
I-129	7.62E-03	2.82E-04	GAS
CO-60	1.22E-02	4.51E-04	CRUD
SR-90	8.30E+05	3.07E+04	PARTICULATE
CS-134	7.93E+04	2.93E+03	VOLATILE
CS-137	1.23E+06	4.56E+04	VOLATILE
PU-241	1.10E+06	4.09E+04	VOLATILE
Y-90	8.30E+05	3.07E+04	PARTICULATE
RU-106	7.02E+03	2.60E+02	PARTICULATE
SB-125	8.05E+03	2.98E+02	PARTICULATE
PM-147	1.28E+05	4.74E+03	PARTICULATE
SM-151	4.62E+03	1.71E+02	PARTICULATE
EU-154	8.05E+04	2.98E+03	PARTICULATE
EU-155	2.81E+04	1.04E+03	PARTICULATE
PU-238	5.00E+04	1.85E+03	PARTICULATE
PU-239	3.86E+03	1.43E+02	PARTICULATE
PU-240	6.65E+03	2.46E+02	PARTICULATE
AM-241	2.48E+04	9.16E+02	PARTICULATE

Table 4.1-3
Pertinent Portions Of The Spreadsheets For Calculating Collective Doses For A Single Shipment
(15 pages)

Maine Yankee

Maine Yankee to the WCS CISF by Rail

State	Rural Pop Density per/sq mi	Rural Distance mile	Rural Population	Suburban Density per/sq mi	Suburban Distance mile	Suburban Population	Urban Density per/sq mi	Urban Distance mile	Urban Population
CT	95.90	10.2	978	1447.70	104.35	151067	8130.70	36.41	296039
IL	21.10	181.18	3823	1235.00	54.28	67036	4687.80	10.38	48659
IN	43.90	88.83	3900	1075.80	80.8	86925	4598.40	9.66	44421
KS	20.40	74	1510	1028.00	16.93	17404	0.00	0.00	0
MA	73.50	10.33	759	1215.40	57.07	69363	7653.00	19.52	149387
ME	79.30	28.54	2263	1049.30	54.45	57134	5644.70	7.40	41771
MO	30.50	258.84	7895	1164.20	116.9	136095	3785.10	8.22	31114
NH	91.40	5.9	539	873.10	25.62	22369	5916.10	3.27	19346
NJ	66.90	18.13	1213	1268.10	50.1	63532	7756.20	28.96	224620
NY	47.50	109.67	5209	1236.10	61.63	76181	16710.70	40.71	680293
OH	40.10	206.65	8287	734.80	59.03	43375	4486.10	5.01	22475
OK	35.40	220.1	7792	1130.60	107.56	121607	6666.10	5.90	39330
PA	54.30	249.26	13535	1030.00	167.84	172875	5758.30	23.71	136529
TX	28.10	389.22	10937	868.90	105.97	92077	5205.70	16.18	84228
WV	63.50	3.43	218	785.00	1.37	1075	0.00	0.00	0
total dist		1854.28			1063.9			215.33	
km		2984.18			1712.18			346.54	
population			68857			1178116			1818210
PD (per/sq km	14.42			430.05			3279.21		
person-rem			2.63E-03			3.92E-02			2.10E-03

Table 4.1-3
Pertinent Portions Of The Spreadsheets For Calculating Collective Doses For A Single Shipment
(Continued)

Maine Yankee

Maine Yankeee to Portland by Barge									
	Rural Pop	Rural	Rural	Suburban	Suburban	Suburban	Urban	Urban	Urban
	Density	Distance	Population	Density	Distance	Population	Density	Distance	Population
State	per/sq mi	mile		per/sq mi	mile		per/sq mi	mile	
ME	13	26.64	346	414.1	1.73	716	3912.1	0.38	1487
total dist		26.64			1.73			0.38	
km		42.87			2.78			0.61	
population			346			716			1487
PD (per/sq km)	5.05			160.83			1519.29		
person-rem			8.27E-05			1.49E-04			1.07E-05

Portland to the WCS CISF by Rail									
	Rural Pop	Rural	Rural	Suburban	Suburban	Suburban	Urban	Urban	Urban
	Density	Distance	Population	Density	Distance	Population	Density	Distance	Population
State	per/sq mi	mile		per/sq mi	mile		per/sq mi	mile	
CT	95.9	10.2	978	1447.7	104.35	151067	8130.7	36.41	296039
IL	21.1	181.18	3823	1235	54.28	67036	4687.8	10.38	48659
IN	43.9	88.83	3900	1075.8	80.8	86925	4598.4	9.66	44421
KS	20.4	74	1510	1028	16.93	17404	0	0	0
MA	73.5	10.33	759	1215.4	57.07	69363	7653	19.52	149387
ME	79.3	12.89	1022	1049.3	28.06	29443	5644.7	2.15	12136
MO	30.5	258.84	7895	1164.2	116.9	136095	3785.1	8.22	31114
NH	91.4	5.9	539	873.1	25.62	22369	5916.1	3.27	19346
NJ	66.9	18.13	1213	1268.1	50.1	63532	7756.2	28.96	224620
NY	47.5	109.67	5209	1236.1	61.63	76181	16710.7	40.71	680293
OH	40.1	206.65	8287	734.8	59.03	43375	4486.1	5.01	22475
OK	35.4	220.1	7792	1130.6	107.56	121607	6666.1	5.9	39330
PA	54.3	249.26	13535	1030	167.84	172875	5758.3	23.71	136529
TX	28.1	389.22	10937	868.9	105.97	92077	5205.7	16.18	84228
WV	63.5	3.43	218	785	1.37	1075	0	0	0
total dist		1838.63			1037.51			210.08	
km		2958.99			1669.71			338.09	
population			67616			1150425			1788576
PD (per/sq km	14.28			430.62			3306.38		
person-rem			2.58E-03			3.83E-02			2.07E-03

This attachment has been completely replaced in response to multiple RAIs

Table 4.1-3
Pertinent Portions Of The Spreadsheets For Calculating Collective Doses For A Single Shipment
(Continued)

Yankee Rowe

Yankee Rowe to Albany by Heavy Haul									
	Rural Pop	Rural	Rural	Suburban	Suburban	Suburban	Urban	Urban	Urban
	Density	Distance	Population	Density	Distance	Population	Density	Distance	Population
State	per/sq mi	mile		per/sq mi	mile		per/sq mi	mile	
MA	3.5	1.55	5	0	0	0	0	0	0
NY	55.1	16.02	883	1814.7	11.23	20379	6491.2	7.24	46996
VT	14	18.13	254	645.7	2.17	1401	5161.4	0.83	4284
total dist		35.7			13.4			8.07	
km		57.45			21.57			12.99	
population			1142			21780			51280
PD (per/sq km	12.42			631.23			2467.78		
person-rem			1.09E-04			1.81E-03			1.48E-04

Albany to the WCS CISF by Rail									
	Rural Pop	Rural	Rural	Suburban	Suburban	Suburban	Urban	Urban	Urban
	Density	Distance	Population	Density	Distance	Population	Density	Distance	Population
State	per/sq mi	mile		per/sq mi	mile		per/sq mi	mile	
IA	57.3	14.28	818	478.6	5.51	2637	0	0	0
IL	21.5	162.85	3501	1398.4	62.55	87470	4854.4	14.51	70437
IN	41.9	90.88	3808	985.4	50.42	49684	4686.5	2.84	13310
KS	28.5	124.58	3551	1194.3	30.92	36928	3876.6	5.26	20391
MO	28.1	176.88	4970	1133.3	20.39	23108	9425.9	5.7	53728
NY	62.5	174.07	10879	1152	160.33	184700	5571.8	25.88	144198
OH	50.4	128.34	6468	1348.7	99.12	133683	4332.3	19.54	84653
OK	29.6	187.56	5552	1107.5	54.46	60314	3532.1	1.87	6605
PA	61.2	18.89	1156	1760	19.45	34232	5934.1	5.51	32697
TX	31.5	314.73	9914	1033.2	131.95	136331	5142.5	17.2	88451
total dist		1393.06			635.1			98.31	
km		2241.92			1022.10			158.21	
population			50618			749087			514470
PD (per/sq km)	14.11			458.06			2032.32		
person-rem			1.93E-03			2.49E-02			5.95E-04

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Table 4.1-3
Pertinent Portions Of The Spreadsheets For Calculating Collective Doses For A Single Shipment
(Continued)

Connecticut Yankee

Haddam Neck to New Haven by Barge									
	Rural Pop	Rural	Rural	Suburban	Suburban	Suburban	Urban	Urban	Urban
	Density	Distance	Population	Density	Distance	Population	Density	Distance	Population
State	per/sq mi	mile		per/sq mi	mile		per/sq mi	mile	
CT	20.6	56.53	1165	1665.6	7.17	11942.352	6749.1	0.82	5534.262
total dist		56.53			7.17			0.82	
km		90.98			11.54			1.32	
population			1165			11942			5534
PD (per/sq km)	8.00			646.85			2621.06		
person-rem			2.78E-04			2.48E-03			4.00E-05

New Haven to the WCS CISF by Rail									
	Rural Pop	Rural	Rural	Suburban	Suburban	Suburban	Urban	Urban	Urban
	Density	Distance	Population	Density	Distance	Population	Density	Distance	Population
State	per/sq mi	mile		per/sq mi	mile		per/sq mi	mile	
AR	37.5	204.70	7676	953.3	96.22	91727	5509.4	4.02	22148
CT	99.8	1.00	100	1182.7	48.83	57751	5494.3	7.74	42526
IL	28.2	183.15	5165	721.8	44.9	32409	3785.7	0.69	2612
IN	46.3	64.76	2998	1361.1	87.14	118606	10054.7	10.6	106580
MA	34.6	35.67	1234	1116.1	26.77	29878	6586	6.68	43994
MO	28.2	76.03	2144	774.2	17.92	13874	0	0	0
NY	61.9	210.68	13041	1056.2	166.21	175551	5671.9	22.95	130170
OH	46.4	139.61	6478	1400.2	109.2	152902	4135.9	20.48	84703
PA	61.2	18.89	1156	1760	19.45	34232	5934.1	5.51	32697
TX	34.3	401.83	13783	1192.8	185.53	221300	6694.6	25.77	172520
total dist		1336.32			802.17			1336.32	
km		2150.60			1290.97			2150.60	
population			13783			928230			637950
PD (per/sq km)	4.01			449.39			185.40		
person-rem			5.26E-04			3.09E-02			7.38E-04

This attachment has been completely replaced in response to multiple RAIs

Table 4.1-3
Pertinent Portions Of The Spreadsheets For Calculating Collective Doses For A Single Shipment
(Continued)

Connecticut Yankee

Haddam Neck to Middletown Junction by Heavy Haul

State	Rural Pop Density per/sq mi	Rural Distance mile	Rural Population	Suburban Density per/sq mi	Suburban Distance mile	Suburban Population	Urban Density per/sq mi	Urban Distance mile	Urban Population
CT	72.1	8.03	579	584.7	5.14	3005	4028	0.12	483
total dist		8.03			5.14			0.12	
km		12.92			8.27			0.19	
population			579			3005			483
PD (per/sq km)	28.00			227.07			1564.30		
person-rem			5.53E-05			2.50E-04			1.40E-06

Middletown Junction to the WCS CISF by Rail

State	Rural Pop Density per/sq mi	Rural Distance mile	Rural Population	Suburban Density per/sq mi	Suburban Distance mile	Suburban Population	Urban Density per/sq mi	Urban Distance mile	Urban Population
AR	37.5	204.7	7676	953.3	96.22	91727	5509.4	4.02	22148
CT	134	0.19	25	1469.2	48.83	71741	5494.3	7.74	42526
IL	28.2	183.15	5165	721.8	44.9	32409	3785.7	0.69	2612
IN	46.3	64.76	2998	1361.1	87.14	118606	10054.7	10.6	106580
MA	34.6	35.67	1234	1116.1	26.77	29878	6586	6.68	43994
MO	28.2	76.03	2144	774.2	17.92	13874	0	0	0
NY	61.9	210.68	13041	1056.2	166.21	175551	5671.9	22.95	130170
OH	46.4	139.61	6478	1400.2	109.2	152902	4135.9	20.48	84703
PA	61.2	18.89	1156	1760	19.45	34232	5934.1	5.51	32697
TX	34.3	401.83	13783	1192.8	185.53	221300	6694.6	25.77	172520
total dist		1335.51			802.17			104.44	
km		2149.30			1290.97			168.08	
population			53701			942219			637950
PD (per/sq km)	15.62			456.16			2372.19		
person-rem			2.05E-03			3.13E-02			7.38E-04

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Table 4.1-3
Pertinent Portions Of The Spreadsheets For Calculating Collective Doses For A Single Shipment
(Continued)

Humboldt Bay

Humboldt Bay To San Franisco by Barge									
	Rural Pop	Rural	Rural	Suburban	Suburban	Suburban	Urban	Urban	Urban
	Density	Distance	Population	Density	Distance	Population	Density	Distance	Population
State	per/sq mi	mile		per/sq mi	mile		per/sq mi	mile	
CA	1.4	10.1	14	8552	0.17	1454			
Ocean	0	324.92	0	0	0	0			
total dist		335.02			0.17			0	
km		539.16			0.27			0.00	
population			14			1454			0
PD (per/sq km)	0.02			3321.22					
person-rem			3.37E-06			3.02E-04			0

San Francisco to the WSC CISF by Rail									
	Rural Pop	Rural	Rural	Suburban	Suburban	Suburban	Urban	Urban	Urban
to wcs rail	Density	Distance	Population	Density	Distance	Population	Density	Distance	Population
State	per/sq mi	mile		per/sq mi	mile		per/sq mi	mile	
AZ	18.6	314.42	5848	1046.6	70.53	73817	4273.7	5.19	22181
CA	35.4	422.09	14942	1318.9	201.64	265943	6675.9	119.68	798972
NM	7.1	156.66	1112	917.5	10.86	9964	0	0	0
TX	9	207.14	1864	1058	28.63	30291	6508.8	14.08	91644
total dist		1100.31			311.66			138.95	
km		1770.78			501.57			223.62	
population			23767			380014			912796
PD (per/sq km)	8.39			473.53			2551.21		
person-rem			9.08E-04			1.26E-02			1.06E-03

This attachment has been completely replaced in response to multiple RAIs

Table 4.1-3
Pertinent Portions Of The Spreadsheets For Calculating Collective Doses For A Single Shipment
(Continued)

Big Rock Point

Big Rock Point to Cadillac by Heavy Haul									
	Rural Pop	Rural	Rural	Suburban	Suburban	Suburban	Urban	Urban	Urban
	Density	Distance	Population	Density	Distance	Population	Density	Distance	Population
State	per/sq mi	mile		per/sq mi	mile		per/sq mi	mile	
MI	21.8	358.37	7812.466	774.8	33.22	25739	0	0	0
total dist		358.37			33.22			0	
km		576.74			53.46			0.00	
population			7812.466			25739			0
PD (per/sq km)	8.47			300.90					
person-rem			7.46E-04			2.14E-03			0.00E+00

Cadillac to the WCS CISF by Rail									
	Rural Pop	Rural	Rural	Suburban	Suburban	Suburban	Urban	Urban	Urban
	Density	Distance	Population	Density	Distance	Population	Density	Distance	Population
State	per/sq mi	mile		per/sq mi	mile		per/sq mi	mile	
IL	26.2	205.63	5388	1094	64.97	71103	4030.1	7.08	28533
IN	57.7	41.27	2381	1283	31.35	40225	4022.5	7.97	32059
KS	28.5	124.58	3551	1194	30.92	36928	3876.6	5.26	20391
MI	45.7	174.43	7971	1155	89.09	102890	5064.2	10.69	54136
MO	32.4	212.71	6892	1314	61.8	81193	7196.5	15.62	112409
OK	29.6	187.56	5552	1108	54.46	60314	3532.1	1.87	6605
TX	31.5	314.73	9914	1033	131.95	136331	5142.5	17.2	88451
total dist		1260.91			464.54			65.69	
km		2029.24			747.61			105.72	
population			41648			528984			342585
PD (per/sq km	12.83			442.23			2025.35		
person-rem			1.59E-03			1.76E-02			3.96E-04

This attachment has been completely replaced in response to multiple RAIs

Table 4.1-3
Pertinent Portions Of The Spreadsheets For Calculating Collective Doses For A Single Shipment
(Continued)

Rancho Seco

Ranch Seco to the WCS CISF by Rail									
	Rural Pop Density	Rural Distance	Rural Population	Suburban Density	Suburban Distance	Suburban Population	Urban Density	Urban Distance	Urban Population
State	per/sq mi	mile		per/sq mi	mile		per/sq mi	mile	
AZ	18.6	314.42	5848	1046.6	70.53	73817	4273.7	5.19	22181
CA	36	407.21	14660	1300.5	189.83	246874	5223.9	73.43	383591
NM	7.1	156.66	1112	917.5	10.86	9964	0	0	0
TX	9	207.14	1864	1058	28.63	30291	6508.8	14.08	91644
total dist		1085.43			299.85			92.7	
km		1746.83			482.56			149.19	
population			23484			360945			497415
PD (per/sq	8.40			467.48			2083.87		
person-rem			8.97E-04			1.20E-02			5.75E-04

Trojan

Trojan to the WCS CISF by Rail									
	Rural Pop Density	Rural Distance	Rural Population	Suburban Density	Suburban Distance	Suburban Population	Urban Density	Urban Distance	Urban Population
State	per/sq mi	mile		per/sq mi	mile		per/sq mi	mile	
AZ	18.6	314.42	5848	1046.6	70.53	73817	4273.7	5.19	22181
CA	35.6	612.1	21791	1245.4	278.52	346869	5102.3	94.7	483188
NM	7.1	156.66	1112	917.5	10.86	9964	0	0	0
OR	29.9	254.54	7611	1044.9	91.89	96016	6650.1	31.22	207616
TX	9	207.14	1864	1058	28.63	30291	6508.8	14.08	91644
total dist		1544.86			480.43			145.19	
km		2486.22			773.18			233.66	
population			38226			556956			804628
PD (per/sq km	9.61			450.22			2152.23		
person-rem			1.46E-03			1.85E-02			9.30E-04

This attachment has been completely replaced in response to multiple RAIs

Table 4.1-3
Pertinent Portions Of The Spreadsheets For Calculating Collective Doses For A Single Shipment
(Continued)

Trojan

Trojan to Portland By Barge

State	Rural Pop Density per/sq mi	Rural Distance mile	Rural Population	Suburban Density per/sq mi	Suburban Distance mile	Suburban Population	Urban Density per/sq mi	Urban Distance mile	Urban Population
OR	11	27.98	308	282.7	3.3	933	0	0	
total dist		27.98			3.3			0	
km		45.03			5.31				
population			308			933			
PD (per/sq km	4			110					
person-rem			7.35E-05			1.94E-04			

Portland to the WCS CISF by Rail

State	Rural Pop Density per/sq mi	Rural Distance mile	Rural Population	Suburban Density per/sq mi	Suburban Distance mile	Suburban Population	Urban Density per/sq mi	Urban Distance mile	Urban Population
AZ	18.6	314.42	5848	1046.6	70.53	73817	4273.7	5.19	22,181
CA	35.6	612.1	21791	1245.4	278.52	346869	5102.3	94.7	483,188
NM	7.1	156.66	1112	917.5	10.86	9964	0	0	0
OR	28.1	234.88	6600	1110.3	79.88	88691	6629.5	30.97	205,316
TX	9	207.14	1864	1058	28.63	30291	6508.8	14.08	91,644
total dist		1525.2			468.42			144.94	
km		2454.58			753.85			233.26	
population			37216			549631			802,328
PD (per/sq km	9.48			455.69			2149.78		
person-rem			1.42E-03			1.83E-02			9.28E-04

This attachment has been completely replaced in response to multiple RAIs

Table 4.1-3
Pertinent Portions Of The Spreadsheets For Calculating Collective Doses For A Single Shipment
(Continued)

LaCrosse

LaCrosse to the WCS CISF by Rail

State	Rural Pop Density per/sq mi	Rural Distance mile	Rural Population	Suburban Density per/sq mi	Suburban Distance mile	Suburban Population	Urban Density per/sq mi	Urban Distance mile	Urban Population
IA	57.3	14.28	818	478.6	5.51	2637	0	0	0
IL	24	165.61	3975	675.9	27.81	18797	4469.4	1.46	6525
KS	23.8	169.24	4028	1209.1	52.29	63224	4157.9	6.81	28315
MO	28.1	176.88	4970	783.3	18.12	14193	8523.2	3.96	33752
OK	38.8	168.52	6539	1240.4	62.87	77984	4791	16.2	77614
TX	32.2	305.57	9839	1034.1	119.34	123409	6083.7	12.96	78845
WI	27.9	95.43	2662	1057.2	16.14	17063	3621.9	2.14	7751
total dist		1095.53			302.08			43.53	
km		1763.09			486.15			70.05	
population			32832			317308			232802
PD (per/sq km)	11.64			407.93			2076.96		
person-rem			1.25E-03			1.06E-02			2.69E-04

La Crosse to Genoa by Barge

State	Rural Pop Density per/sq mi	Rural Distance mile	Rural Population	Suburban Density per/sq mi	Suburban Distance mile	Suburban Population	Urban Density per/sq mi	Urban Distance mile	Urban Population
IL	0	27.2	0	0	0	0	0		
IN	64	0.91	58	0	0	0			
MI	627.18	3.2	2007	3869.3	19.2	74291			
total dist		31.31			19.2			0	
km		50.39			30.90			0.00	
population			2065			74291			0
PD (per/sq km	25.62			1502.67					
person-rem			4.93E-04			1.54E-02			0

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Table 4.1-3
Pertinent Portions Of The Spreadsheets For Calculating Collective Doses For A Single Shipment
(Continued)

LaCrosse

Genoa to the WCS CISF by Rail									
	Rural Pop	Rural	Rural	Suburban	Suburban	Suburban	Urban	Urban	Urban
	Density	Distance	Population	Density	Distance	Population	Density	Distance	Population
State	per/sq mi	mile		per/sq mi	mile		per/sq mi	mile	
IA	57.3	14.28	818	478.6	5.51	2637	0	0	0
IL	24	165.61	3975	675.9	27.81	18797	4469.4	3.12	13945
KS	23.8	169.24	4028	1209.1	52.29	63224	4157.9	6.81	28315
MO	28.1	176.88	4970	783.3	18.12	14193	8523.2	3.96	33752
OK	38.8	168.52	6539	1240.4	62.87	77984	4791	16.2	77614
TX	32.2	305.57	9839	1034.1	119.34	123409	6083.7	12.96	78845
WI	19.2	84.85	1629	691.2	8.22	5682	0	0	0
total dist		1084.95			294.16			43.05	
km		1746.06			473.41			69.28	
population			31798			305926			232471
PD (per/sq km)	11.38			403.89			2097.13		
person-rem			1.21E-03			1.02E-02			2.69E-04

Zion

Zion to the WCS CISF by Rail									
	Rural Pop	Rural	Rural	Suburban	Suburban	Suburban	Urban	Urban	Urban
	Density	Distance	Population	Density	Distance	Population	Density	Distance	Population
State	per/sq mi	mile		per/sq mi	mile		per/sq mi	mile	
IA	45.2	204.71	9253	863.8	90.19	77906	3794.6	3.33	12636
IL	42.4	65.96	2797	1498.1	71.02	106395	4892.8	28.62	140032
KS	28.5	124.58	3551	1194.3	30.92	36928	3876.6	5.26	20391
MO	28.9	108.12	3125	1447	20.75	30025	8156.5	2.38	19412
OK	29.6	187.56	5552	1107.5	54.46	60314	3532.1	1.87	6605
TX	31.5	314.73	9914	1033.2	131.95	136331	5142.5	17.2	88451
total dist		1005.66			399.29			58.66	
km		1618.46			642.60			94.40	
population			34191			447899			287527
PD (per/sq km)	13.20			435.63			1903.56		
person-rem			1.31E-03			1.49E-02			3.32E-04

Table 4.1-3
Pertinent Portions Of The Spreadsheets For Calculating Collective Doses For A Single Shipment
(Continued)

Zion

Zion to Rock Island (Davenport) by Barge

State	Rural Pop Density per/sq mi	Rural Distance mile	Rural Population	Suburban Density per/sq mi	Suburban Distance mile	Suburban Population	Urban Density per/sq mi	Urban Distance mile	Urban Population
IL	0	27.2	0	0	0	0	0	0	0
IN	64	0.91	58	0	0	0	0	0	0
MI	3.2	627.18	2007	19.82	3869.3	76690	0	0	0
total dist		655.29			3869.3			0	
km		1054.59			6227.05			0	
population			2065			76690			0
PD (per/sq km)	1.22			7.70					
person-rem			4.93E-04			1.59E-02			0.00E+00

Rock Island (Davenport) to the WCS CISF by Rail

State	Rural Pop Density per/sq mi	Rural Distance mile	Rural Population	Suburban Density per/sq mi	Suburban Distance mile	Suburban Population	Urban Density per/sq mi	Urban Distance mile	Urban Population
IA	57.3	14.28	818	478.6	5.51	2637	0	0	0
IL	23	81.87	1883	1164.8	24.07	28037	3979.7	3.12	12417
KS	23.8	169.24	4028	1209.1	52.29	63224	4157.9	6.81	28315
MO	28.1	176.88	4970	783.3	18.12	14193	8523.2	3.96	33752
OK	38.8	168.52	6539	1240.4	62.87	77984	4791	16.2	77614
TX	32.2	305.57	9839	1034.1	119.34	123409	6083.7	12.96	78845
total dist		916.36			282.2			43.05	
km		1474.74			454.16			69.28	
population			28077			309484			230943
PD (per/sq km)	11.90			425.90			2083.35		
person-rem			1.07E-03			1.03E-02			2.67E-04

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Table 4.1-3
Pertinent Portions Of The Spreadsheets For Calculating Collective Doses For A Single Shipment
(Continued)

Crystal River

Crystal River to the WCS CISF by Rail

State	Rural Pop Density per/sq mi	Rural Distance mile	Rural Population	Suburban Density per/sq mi	Suburban Distance mile	Suburban Population	Urban Density per/sq mi	Urban Distance mile	Urban Population
AL	48.9	191.5	9364	1088.1	104.49	113696	6476.7	7.32	47409
AR	32.9	191.23	6291	970.8	95.38	92595	5509.4	4.02	22148
FL	42.8	127.9	5474	717.6	39.82	28575	0	0	0
GA	30.7	219.06	6725	842.8	62.1	52338	3442.6	0.3	1033
MS	45	22.65	1019	989.2	11.42	11297	3403.9	0.02	68
TN	38.2	56.03	2140	1674.3	20.92	35026	5018.5	10.92	54802
TX	34.3	401.83	13783	1192.8	185.53	221300	6694.6	25.77	172520
total dist		1210.2			519.66			48.35	
km		1947.63			836.31			77.81	
population			44797			554826			297980
PD (per/sq km)	14.38			414.64			2393.43		
person-rem			1.71E-03			1.84E-02			3.45E-04

Kewaunee

Kewaunee to Green Bay by Heavy Haul

State	Rural Pop Density per/sq mi	Rural Distance mile	Rural Population	Suburban Density per/sq mi	Suburban Distance mile	Suburban Population	Urban Density per/sq mi	Urban Distance mile	Urban Population
WI	34.7	21.17	735	1258.6	11.94	15028	3634.4	1.48	5379
total dist		21.17			11.94			1.48	
km		34.07			19.22			2.38	
population			735			15028			5379
PD (per/sq k	13.48			488.79			1411.44		
person-rem			7.01E-05			1.25E-03			1.55E-05

Table 4.1-3
Pertinent Portions Of The Spreadsheets For Calculating Collective Doses For A Single Shipment
(Continued)

Kewaunee

Green Bay to the WCS CISF by Rail									
	Rural Pop	Rural	Rural	Suburban	Suburban	Suburban	Urban	Urban	Urban
	Density	Distance	Population	Density	Distance	Population	Density	Distance	Population
State	per/sq mi	mile		per/sq mi	mile		per/sq mi	mile	
AR	37.5	204.7	7676	953.3	96.22	91727	5509.4	4.02	22148
IL	36.1	233.58	8432	1328.4	130.28	173064	4962.6	50.68	251505
MO	28.2	76.03	2144	774.2	17.92	13874	0	0	0
TX	34.3	401.83	13783	1192.8	185.53	221300	6694.6	25.77	172520
WI	60.8	70.34	4277	1506.3	82.39	124104	4820.2	13.94	67194
total dist		986.48			512.34			94.41	
km		1587.59			824.53			151.94	
population			36312			624068			513366
PD (per/sq k	14.30			473.05			2111.73		
person-rem			1.39E-03			2.08E-02			5.94E-04

San Onofre

San Onofre to the WCS CISF by Rail									
	Rural Pop	Rural	Rural	Suburban	Suburban	Suburban	Urban	Urban	Urban
	Density	Distance	Population	Density	Distance	Population	Density	Distance	Population
State	per/sq mi	mile		per/sq mi	mile		per/sq mi	mile	
AZ	18.6	314.42	5848	1046.6	70.53	73817	4273.7	5.19	22181
CA	23.3	139.13	3242	1723.7	76.58	132001	6396.8	65.64	419886
NM	7.1	156.66	1112	917.5	10.86	9964	0	0	0
TX	9	207.14	1864	1058	28.63	30291	6508.8	14.08	91644
total dist		817.35			186.6			84.91	
km		1315.40			300.30			136.65	
population			12066			246072			533710
PD (per/sq km	5.73			512.13			2441.05		
person-rem			4.61E-04			8.18E-03			6.17E-04

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Table 4.1-3
Pertinent Portions Of The Spreadsheets For Calculating Collective Doses For A Single Shipment
(Concluded)

WCS CISF to Yucca Mountain

WCS CISF to Yucca Mountain by Rail									
	Rural Pop	Rural	Rural	Suburban	Suburban	Suburban	Urban	Urban	Urban
	Density	Distance	Population	Density	Distance	Population	Density	Distance	Population
State	per/sq mi	mile		per/sq mi	mile		per/sq mi	mile	
AZ	21.9	299.28	6554	1338.1	87.95	117686	7165.7	37.01	265203
CA	3.1	296.94	921	266.4	2.36	629	0	0	0
NM	13.7	161.02	2206	1030.7	29.01	29901	4004.3	2.76	11052
NV	3.2	12.65	40	178	0.63	112	0	0	0
TX	11.7	207.95	2433	1349.7	46.37	62586	5180	18.64	96555
total dist		977.84			166.32			58.41	
km		1573.68			267.67			94.00	
population			12154			210913			372810
PD (per/sq km)	4.83			492.48			2478.74		
person-rem			4.64E-04			7.01E-03			4.31E-04

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Table 4.1-4
Calculation Spreadsheet Used to Assess Occupational Doses per Shipment from Routine, Incident-Free Transportation of SNF

			OCCUPATIONAL DOSES PER SHIPMENT FROM ROUTINE, INCIDENT-FREE TRANSPORTARTIONSHIPMENT					
			Maine Yankee to WCS					
						TRAIN CREW IN TRANSIT	DISTANCE	TRIP DOSE
						3 PEOPLE		
	RADTRAN OUTPUT					person-rem/km	km	person-rem
	Link	CREW			Rural	7.78E-07	2984.18	2.32E-03
	GENR	7.78E-07			Suburan	7.78E-07	1712.18	1.33E-03
	GENS	7.78E-07			Urban	1.31E-06	346.54	4.54E-04
	GENU	1.31E-06						
							TOTAL	4.11E-03
	CLASSIFICATION-NONLINK					**RAIL YARD WORKERS**	Hours	Dose
		1.65E-02				person-rem		
						Classification Stop	27	1.65E-02
						Railorad Tranfer	4	2.44E-03
	HANDLING					**HANDLERS**		
	LINE-SOURCE					5 PEOPLE		
						person-rem	5	4.01E-01
						ESCORTS		
						2 PEOPLE		
						Escorts assumed to have		
						25% greater dose than crew		3.42E-03
						NUREG 2125 (page B-52)		
	STOP	DISTANCE	DOSE					
		m	person-rem					
	INSPECTOR	2	9.55E-02			**INSPECTORS**		DOSE
						rem/inspection		person-rem
						2 meters for 4 hours		9.55E-02
	STOP	DISTANCE	DOSE			**FIRST RESPONDERS**		DOSE
		m	person-rem			PERSON-REM/RESPONDER		person-rem
	RESPONDER	3	1.60E-01			3 meters for 10 hours		1.60E-01

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