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Transportation Health and Safety

Calculation/Analysis Documentation

in Support of the Final EIS

for

the Yucca Mountain Repository

CAL-HSS-ND-000003

December 2001

Prepared for:

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Errata in Transportation H&S Calculation Package

A general note: I asked Dawn about using URLs as references. Apparently it is OK if the URL works

Section	Page	Paragraph or Table or Bullet	Error	Correction
2.1	1	1st bullet	(DIRS 137713-DOE 1998, p. 1-9)	Delete citation: (DIRS 137713-DOE 1998, p. 1-9)
3.3.2.2	43		(DIRS 155347-CRWMS M&O 1999, all)	Citation should be: (DIRS 154822—all; DIRS 154448 – Section 7.6)
3.3.3	45	4th bullet	(DIRS 155347-CRWMS M&O 1999, all)	Citation should be: (DIRS 154822—all; DIRS 154448 – Section 7.6)
3.3.4	46		(DIRS 155931-Knop 2001, all)	Delete citation and insert "Attachment 33A"
3.4.5	56	2nd full paragraph	Missing reference and citation	Add DIRS 157541- Bland, 2000, to the citation (136698-Riddel and Schwer 1999, all).
4.1.2.3	61	1st paragraph of section	Reference to DIRS 105155	Delete citation: (DIRS 105155-DOE 1999, pp. 6-21 to 6-24)
4.3.3	88	6th bullet	DIRS 104597-Battelle 1998, all;	First citation should read: DIRS 157524 Daust, 1998, all
5.1.2.2	102	1st complete par.	DIRS 104800, 1999	Citation should read: DIRS 104849, CRWMS M&O 1997
5.2.2.2	108		DIRS 104800, 1999	Citation should read (DIRS 157536, Jason Technologies, 2001, all)
5.3. 1.2	118	3rd paragraph of section	(DIRS 152985- DOE 2000, Section 3.1.2)	Citation should read (DIRS157518 Jason Technologies Corporation 2001, Section 3.0)
6.3	197	Top of page	DIRS 105155 (DOE 1999, pp. J-109-J-110)	Citation should read (DIRS157518 Jason Technologies Corporation 2001, Section 3.0)
6.3	200	Second item in list below Table 6-9	(DIRS 104800-CRWMS M&O 1999, Addendum 15)	Citation should read: [DIRS 148081 BTS (Bureau of Transportation Statistics) 1999 Table 2-17]

CONTENTS

APPENDICES AND ATTACHMENTS

Note: **Appendices are appended to the document, in print.**

Note: **Attachments are appended to the document electronically on a read-only compact disk that accompanies the document; Table references are to tables in the calculation package.**

Attachment Name	Attachment Description
Transportation Database	ACCESS 2000 relational database for calculating impacts
Database User Guide	Word document; user guide for the Transportation Database
Attachment 1A	Word document; Transportation Database verification documentation
Attachment 2A	Excel spreadsheet; SNF shipment data (Table 2-14)
Attachment 31A	Route distance and population density data; HIGHWAY and INTERLINE input and output text files (Tables 3-7, 3-11, 3-12)
Attachment 32A	HIGHWAY and INTERLINE source code ; text file
Attachment 33A	Nevada routing and population data including maps generated by Arcview/ArcInfo (Table 3-31)
Attachment 34A	Nevada demographic and REMI projections; text file (Table 3-34)
Attachment 41A	Word document; average isotope inventories (Table 4-3)
Attachment 42A	RADTRAN 5 incident-free input and output files; text files (Table 4-22). Excel spreadsheet; offline calculations and compilation of RADTRAN incident free unit risk factors (Table 4-22).
Attachment 532A	Excel spreadsheets; release fraction calculations for DOE fuels and HLW (Table 5-15)
Attachment 532B	Excel spreadsheet; ingestion dose calculation from ground deposition. RADTRAN 5 input and output text files for other accident per-curie doses for each isotope; RADTRAN input and output text files for loss of shielding (Table 5-54)
Attachment 53A	RISKIND input and output text files for the maximum foreseeable accident (Table 5-62)
Attachment 54A	RISKIND input and output text files sabotage and terrorism vents (Table 5-71)
Attachment 63A	Excel spreadsheet; calculation of impacts of transporting materials, workers, and site-generated waste
Attachment 8A	Excel spreadsheet; calculation of impacts of rail line construction
Attachment H5A	WebTRAGIS input and output files for Appendix H. Access Database for calculating impacts presented in Appendix H.

TABLES

FIGURES

LIST OF ACROYNMS

BWR	boiling-water reactor
CAIRS	Computerized Accident and Incident Reporting System
CALVIN	CRWMS Analysis and Logistics Visually Interactive model
DEIS	Draft Environmental Impact Statement
DLG	digital line graph
DOE	U.S. Department of Energy
DRG	digital raster graph
EIS	environmental impact statement
FEIS	Final Environmental Impact Statement
FTE	full-time equivalent
GIS	Geographic Information System
GTCC	Greater Than Class C (low-level radioactive waste)
HLW	high-level radioactive waste
IMT	intermodal transfer (station)
INEEL	Idaho National Engineering and Environmental Laboratory
LCF	latent cancer fatality
LWC	lost workday case
MEI	maximally exposed individual
MTHM	metric tons of heavy metal
ORNL	Oak Ridge National Laboratory
PWR	pressurized-water reactor
SNF	spent nuclear fuel
SPAR	Special Performance Assessment Required (waste)
SRS	Savannah River Site
TRC	total recordable case

1.0 PURPOSE

The purpose of this calculation package is to document the methods and references used to estimate the transportation impacts presented in the *Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (FEIS). Specifically, this calculation package addresses radiological and nonradiological transportation and transportation-related activities. For each impact category analyzed, this document discusses the methods, assumptions, use of computer software and models, and calculations/analysis and results.

Also included as Attachment 1A to this calculation package is the Transportation Database Verification document for the Yucca Mountain Environmental Impact Statement. This attachment documents verification activities performed on the Yucca Mountain EIS Transportation Database.

1.1 Use of Commercial Software

Commercial off-the-shelf software used for analyses in this calculation package includes Microsoft® Excel 97 and 2000, and Microsoft® Access 2000. Excel may be run on a personal computer under the Microsoft® operating systems Windows 98, Windows Millennium edition (Me), and Windows 2000. Reference to the use of spreadsheets throughout the text of the calculation package implies the use of one of these versions of Excel under one of these operating systems. Microsoft® Access was used for the database application, which will be referred to in this document simply as "the database."

The subsections of each section that are titled "Use of Computer Software/Models" discuss software and models different from Microsoft® off-the-shelf software.

2.0 SHIPMENTS

2.1 Introduction

This section documents the methods and references used to estimate the number of shipments from each generator site presented in the FEIS for the following:

- Base Case (Proposed Action): 70,000 metric tons of heavy metal (MTHM), of which 63,000 MTHM will be commercial spent nuclear fuel (SNF) and 7,000 MTHM will be Department of Energy (DOE) SNF (2,333 MTHM) and high-level radioactive waste (HLW) (4,667 MTHM). The base case will also include as much as 50 MTHM of plutonium surplus fissile materials as mixed oxide spent fuel and as immobilized plutonium (DIRS 137713-DOE 1998, p. 1-9).

- Module 1: Base case plus the remainder of commercial SNF (as much as 105,000 MTHM), the remainder of DOE SNF and the remainder of HLW.

- Module 2: All material in Module 1 plus DOE Special-Performance-Assessment-Required (SPAR) waste and commercial Greater-Than-Class-C (GTCC) waste.

Section 2.5 presents (1) a summary of the shipments for each material type for the Proposed Action and for Modules 1 and 2 and (2) the number of shipments from each generator site for both the Proposed Action and Modules 1 and 2.

2.2 Method

2.2.1 COMMERCIAL SPENT NUCLEAR FUEL

The number of commercial SNF shipments was estimated using the CRWMS Analysis and Logistics Visually Interactive model (CALVIN) (DIRS 134391-CRWMS M&O 1998, all; DIRS 157206-CRWMS-M&O, 2000, all) provides the output from the CALVIN model used to estimate shipment numbers.

2.2.2 DEPARTMENT OF ENERGY SPENT NUCLEAR FUEL

The number of DOE SNF shipments was estimated based on the data in Appendix A (including radionuclide information) and information on the number of canisters per cask provided by the DOE Spent Nuclear Fuel Program (DIRS 104778-Jensen 1998, all). The number of canisters per cask and the number of shipments are presented in Section 2.5. As discussed above, under the Proposed Action, 2,333 MTHM of DOE SNF would be shipped to Yucca Mountain. For Modules 1 and 2, a total of approximately 2,500 MTHM would be shipped.

2.2.3 HIGH-LEVEL RADIOACTIVE WASTE

The number of HLW shipments was estimated based on data provided by the *Waste Quantity, Mix and Throughput Study* (DIRS 100265-CRWMS M&O 1997, all). Specifically, in addition to radionuclide information, Section 2.5 provides the number of canisters of HLW at each site (West Valley, Idaho National Environmental and Engineering Laboratory [INEEL], Savannah River Site [SRS], and Hanford). The assumption of one HLW canister per truck shipment and five per rail shipment was then used to estimate the number of shipments.

2.2.4 GTCC WASTE AND DOE SPAR WASTE

The analysis estimated the number of shipments of GTCC and SPAR waste by assuming that 10 cubic meters (about 350 cubic feet) would be shipped in a rail cask and 2 cubic meters (about 71 cubic feet) would be shipped in a truck cask. The analysis assumed that sealed sources and GTCC waste identified as "other" would be shipped from the DOE SRS. For SPAR waste, the same volume-per-cask assumptions were used. However, SPAR waste is analyzed shipped from four DOE sites (INEEL, Hanford, SRS, and West Valley). Naval reactor and Argonne East SPAR wastes were assumed to be shipped from INEEL, and Oak Ridge National Laboratory (ORNL) SPAR waste was assumed to be shipped from SRS. The estimated volume of GTCC and SPAR waste from each generator site is presented in Section 2.5.

2.3 Assumptions

The numbers of shipments for the FEIS were evaluated in a manner similar to the evaluation in the Draft EIS (DEIS) (DIRS 105155-DOE 1999, pp. J-12 to J-22). The evaluation was based on the following assumptions:

- For the mostly legal-weight truck scenario, shipments were assumed to use legal-weight trucks except for shipments of naval SNF. Under this scenario, naval SNF would have to be shipped by rail to Nevada and in Nevada by heavy-haul truck to Yucca Mountain because of the size and weight of the shipping container (cask) that would be used.

- For the mostly rail scenario, the analysis assumed that all sites would ship by rail. The analysis assumed that 23 generator sites that do not have direct rail service but could handle large casks would ship by heavy-haul truck to nearby railheads with intermodal capability. The Hope Creek/Salem reactor site is counted as one site in the 23 generator sites with indirect rail access. However, Hope Creek and Salem have different rail access distances (see Table 3-3). Also, 6 of the 23 generator sites with indirect rail access would ship by legal-weight truck until reactor shutdown, when it is assumed the cask handling capability would be upgraded to handle a rail cask.

- Of the 23 generator sites that do not have direct rail service but could handle large casks, 16 could ship by barge to nearby railheads with intermodal capability. The 23 indirect rail sites are listed below. The Hope Creek/Salem reactor site is counted as one site in the 23 generator sites with indirect rail access. However, Hope Creek and Salem have different barge access distances (see the discussion in Section 3.1.2 and Table 3-3). The indirect sites that are also located on or near a navigable waterway are also noted in the list below.

1. Big Rock Point
2. Browns Ferry - Barge
3. Callaway
4. Calvert Cliffs - Barge
5. Conn Yankee (Haddam Neck) - Barge
6. Cooper - Barge
7. Diablo Canyon - Barge
8. Fort Calhoun
9. Ginna
10. Grand Gulf - Barge
11. Hope Creek/Salem - Barge
12. Indian Point - Barge
13. Kewaunee - Barge
14. Oconee
15. Oyster Creek - Barge
16. Palisades - Barge
17. Peach Bottom
18. Pilgrim - Barge
19. Point Beach - Barge
20. St Lucie - Barge
21. Surry - Barge
22. Turkey Point - Barge
23. Yankee-Rowe

The six sites listed below do not have the capability to load a rail cask. However, upon permanent plant shutdown, it is assumed that these six sites would receive upgrades to handle a rail cask:

1. Crystal River
2. St Lucie
3. Pilgrim 1
4. Monticello
5. Ginna
6. Indian Point (Units 1, 2, and 3)

- The commercial SNF shipment provided from the CALVIN model included commercial SNF shipments from Hanford, West Valley, and INEEL. The DOE SNF data also included commercial SNF at DOE sites. These shipments were assumed to be addressed in the DOE SNF data and were deleted from the commercial SNF shipments provided from the CALVIN model. This included shipments from Hanford, West Valley, and INEEL.

- For DOE SNF (DIRS 104778-Jensen 1998, all; DIRS 148240-Dirkmaat 1998, all) the number of canisters per cask is:

  One 17-inch-diameter canister or one 24-inch-diameter canister per truck cask
  Nine 17-inch-diameter canisters per rail cask
  Four 24-inch-diameter canisters per rail cask

- For HLW, it was assumed that there would be one canister per truck shipment and five canisters per rail shipment (DIRS 100265-CRWMS M&O 1997, all).

- GTCC and SPAR waste:

  2 cubic meters (71 cubic feet) per legal-weight shipments
  10 cubic meters (353 cubic feet) per rail shipments

2.4 Use of Computer Software and Models

The CALVIN computer program (DIRS 134391-CRWMS M&O 1998, all) was used to estimate the numbers of shipments of SNF from commercial sites. This program uses information on SNF stored at each site and an assumed scenario for picking up the spent fuel from each site. The program also uses information on the capacity of shipping casks that could be used.

Section 1.1 discusses other software used in to estimate transportation impacts.

2.5 Calculation/Analysis and Results

The numbers of shipments for the mostly legal-weight truck and mostly rail scenarios are listed in Table 2-1. Section 2.5.1 presents the estimates of commercial SNF shipments for both the Proposed Action and the modules. Section 2.5.2 presents the estimate of shipments of DOE SNF. Section 2.5.3 presents the estimates of shipments for HLW. Finally, Section 2.5.4 presents the estimate of shipments of GTCC waste and DOE SPAR waste. The number of naval SNF shipments is included in Table 2-1.

2.5.1 COMMERCIAL SPENT NUCLEAR FUEL

The number of commercial SNF shipments was provided in DIRS 157206-CRWMS M&O 2000 (all). Shipments were provided by mode, reactor site, and year for the Proposed Action and Modules 1 and 2. Tables 2-2 and 2-3 list the total number of shipments from commercial reactor sites for the mostly legal-weight truck and the mostly rail scenarios, respectively, for the Proposed Action and for Modules 1 and 2.

Table 2-1. Summary of shipments.

Category	Proposed Action			
	Mostly truck		Mostly rail	
	Truck	**Rail**	**Truck**	**Rail**
Commercial SNF[a]	41,001	0	1,079	7,218
DOE HLW[b]	8,315	0	0	1,663
DOE SNF[b,c]	3,470	300	0	765
GTCC[d]	0	0	0	0
SPAR[d]	0	0	0	0
	52,786	**300**	**1,079**	**9,646**
Module 1				
Commercial SNF	79,684	0	3,122	12,989
DOE HLW	22,280	0	0	4,458
DOE SNF	3,721	300	0	796
GTCC	0	0	0	0
SPAR	0	0	0	0
	105,685	**300**	**3,122**	**18,243**
Module 2				
Commercial SNF	79,684	0	3,122	12,989
DOE HLW	22,280	0	0	4,458
DOE SNF	3,721	300	0	796
GTCC	1,096	0	0	282
SPAR	1,763	55	0	410
	108,544	**355**	**3,122**	**18,935**

a. Source: DIRS 157206-CRWMS M&O 2000, all.
b. DIRS 100265-CRWMS M&O 1997, all.
c. DIRS 104778-Jensen 1998, all.

Table 2-2. Shipments of commercial SNF, mostly legal-weight truck scenario[a]. (1 of 3)

Site	Reactor	State	Fuel type	Proposed Action (2010-2033)	Modules 1 and 2 (2010-2048)
Browns Ferry	Browns Ferry 1	AL	B[b]	738	1,550
	Browns Ferry 3	AL	B	324	807
Joseph M. Farley	Joseph M. Farley 1	AL	P[c]	363	779
	Joseph M. Farley 2	AL	P	330	843
Arkansas Nuclear One	Arkansas Nuclear One, Unit 1	AR	P	362	645
	Arkansas Nuclear One, Unit 2	AR	P	432	905
Palo Verde	Palo Verde 1	AZ	P	383	694
	Palo Verde 2	AZ	P	375	691
	Palo Verde 3	AZ	P	360	716
Diablo Canyon	Diablo Canyon 1	CA	P	359	971
	Diablo Canyon 2	CA	P	370	1,130
Humboldt Bay	Humboldt Bay	CA	B	44	44
Rancho Seco	Rancho Seco 1	CA	P	124	124
San Onofre	San Onofre 1	CA	P	52	52
	San Onofre 2	CA	P	408	817
	San Onofre 3	CA	P	393	829
Haddam Neck	Haddam Neck	CT	P	255	255
Millstone	Millstone 1	CT	B	321	321
	Millstone 2	CT	P	361	694
	Millstone 3	CT	P	310	1,008
Crystal River	Crystal River 3	FL	P	277	621
St. Lucie	St. Lucie 1	FL	P	426	849
	St. Lucie 2	FL	P	380	987
Turkey Point	Turkey Point 3	FL	P	291	574
	Turkey Point 4	FL	P	292	570
Edwin I. Hatch	Edwin I. Hatch 1	GA	B	939	1,820
Vogtle	Vogtle 1	GA	P	725	1,379
Duane Arnold	Duane Arnold	IA	B	324	576
Braidwood	Braidwood 1	IL	P	565	1,142
Byron	Byron 1	IL	P	617	1,136
Clinton	Clinton 1	IL	B	363	636
Dresden/Morris	Dresden 1	IL	B	76	76
	Dresden 2	IL	B	459	726
	Dresden 3	IL	B	514	760
	Morris[d]	IL	B	319	319
	Morris[d]	IL	P	88	88
LaSalle	LaSalle 1	IL	B	769	2,080
Quad Cities	Quad Cities 1	IL	B	979	1,567
Zion	Zion 1	IL	P	557	557
Wolf Creek	Wolf Creek 1	KS	P	396	678
River Bend	River Bend 1	LA	B	353	636
Waterford	Waterford 3	LA	P	374	607
Pilgrim	Pilgrim 1	MA	B	322	575
Yankee-Rowe	Yankee-Rowe 1	MA	P	134	134
Calvert Cliffs	Calvert Cliffs 1	MD	P	867	1,612
Maine Yankee	Maine Yankee	ME	P	356	356
Big Rock Point	Big Rock Point	MI	B	110	111
D. C. Cook	D. C. Cook 1	MI	P	832	1,759
Fermi	Fermi 2	MI	B	377	662
Palisades	Palisades	MI	P	409	660

Table 2-2. Shipments of commercial SNF, mostly legal-weight truck scenario[a]. (2 of 3)

Site	Reactor	State	Fuel type	Proposed Action (2010-2033)	Modules 1 and 2 (2010-2048)
Monticello	Monticello	MN	B	257	435
Prairie Island	Prairie Island 1	MN	P	665	1,109
Callaway	Callaway 1	MO	P	435	701
Grand Gulf	Grand Gulf 1	MS	B	592	1,383
Brunswick	Brunswick 1	NC	P	40	40
	Brunswick 2	NC	P	36	36
	Brunswick 1	NC	B	281	702
	Brunswick 2	NC	B	282	657
Shearon Harris	Shearon Harris 1	NC	P	289	549
	Shearon Harris	NC	B	152	152
McGuire	McGuire 1	NC	P	372	932
	McGuire 2	NC	P	419	1,069
Cooper Station	Cooper Station	NE	B	272	621
Fort Calhoun	Fort Calhoun	NE	P	260	457
Seabrook	Seabrook 1	NH	P	277	590
Oyster Creek	Oyster Creek 1	NJ	B	451	658
Salem/Hope Creek	Salem 1	NJ	P	329	725
	Salem 2	NJ	P	304	826
	Hope Creek	NJ	B	444	796
James A. FitzPatrick/ Nine Mile Point	James A. FitzPatrick	NY	B	413	732
	Nine Mile Point 1	NY	B	426	628
	Nine Mile Point 2	NY	B	387	722
Ginna	Ginna	NY	P	320	472
Indian Point	Indian Point 1	NY	P	40	40
	Indian Point 2	NY	P	400	805
	Indian Point 3	NY	P	285	694
Davis-Besse	Davis-Besse 1	OH	P	343	786
Perry	Perry 1	OH	B	293	528
Trojan	Trojan	OR	P	195	195
Beaver Valley	Beaver Valley 1	PA	P	309	649
	Beaver Valley 2	PA	P	248	472
Limerick	Limerick 1	PA	B	740	1,354
Peach Bottom	Peach Bottom 2	PA	B	567	1,023
	Peach Bottom 3	PA	B	575	1,035
Susquehanna	Susquehanna 1	PA	B	1,044	2,482
Three Mile Island	Three Mile Island 1	PA	P	320	654
Catawba	Catawba 1	SC	P	327	555
	Catawba 2	SC	P	310	574
Oconee	Oconee 1	SC	P	970	1,668
	Oconee 3	SC	P	324	666
H. B. Robinson	H. B. Robinson 2	SC	P	249	470
Summer	Summer 1	SC	P	281	713
Sequoyah	Sequoyah	TN	P	644	1,768
Watts Bar	Watts Bar 1	TN	P	158	552
Comanche Peak	Comanche Peak 1	TX	P	665	1,409
South Texas	South Texas 1	TX	P	271	614
	South Texas 2	TX	P	257	590
North Anna	North Anna 1	VA	P	675	1,588
Surry	Surry 1	VA	P	863	1,457

Table 2-2. Shipments of commercial SNF, mostly legal-weight truck scenario[a]. (3 of 3)

Site	Reactor	State	Fuel type	Proposed Action (2010-2033)	Modules 1 and 2 (2010-2048)
Vermont Yankee	Vermont Yankee 1	VT	B	380	613
Columbia Generating Station	Columbia Generating Station	WA	B	415	1,006
Kewaunee	Kewaunee	WI	P	306	516
LaCrosse	LaCrosse	WI	B	37	37
Point Beach				6	
				5	1,0
	Point Beach	WI	P	3	51
Total BWR[b]				**15,229**	**28,719**
Total PWR[c]				**25,772**	**50,965**

a. Source: DIRS 157206-CRWMS M&O 2000, all.
b. B = boiling-water reactor (BWR).
c. P = pressurized-water reactor (PWR).
d. Morris is a storage facility located close to the three Dresden reactors.

Table 2-3. Shipments of commercial SNF, mostly rail scenario[a]. (1 of 3)

Site	Reactor	State	Fuel type	Cask	Proposed Action 2010-2033	Modules 1 and 2 2010-2048
Browns Ferry	Browns Ferry 1	AL	B[b]	Rail	122	247
	Browns Ferry 3	AL	B	Rail	51	120
Joseph M. Farley	Joseph M. Farley 1	AL	P[c]	Rail	57	132
	Joseph M. Farley 2	AL	P	Rail	53	131
Arkansas Nuclear One	Arkansas Nuclear One, Unit 1	AR	P	Rail	57	108
	Arkansas Nuclear One, Unit 2	AR	P	Rail	64	149
Palo Verde	Palo Verde 1	AZ	P	Rail	65	97
	Palo Verde 2	AZ	P	Rail	62	94
	Palo Verde 3	AZ	P	Rail	66	102
Diablo Canyon	Diablo Canyon 1	CA	P	Rail	60	148
	Diablo Canyon 2	CA	P	Rail	61	160
Humboldt Bay	Humboldt Bay	CA	B	Rail	6	6
Rancho Seco	Rancho Seco 1	CA	P	Rail	21	21
San Onofre	San Onofre 1	CA	P	Rail	9	9
	San Onofre 2	CA	P	Rail	65	131
	San Onofre 3	CA	P	Rail	64	137
Haddam Neck	Haddam Neck	CT	P	Rail	40	40
Millstone	Millstone 1	CT	B	Rail	91	91
	Millstone 2	CT	P	Rail	115	199
	Millstone 3	CT	P	Rail	49	138
Crystal River	Crystal River 3	FL	P	Rail	25	17
	Crystal River 3	FL	P	Truck/Rail	133	437
St Lucie	St. Lucie 1	FL	P	Rail	12	13
	St. Lucie 1	FL	P	Truck	358	751
	St. Lucie 2	FL	P	Rail	61	147
Turkey Point	Turkey Point 3	FL	P	Rail	52	85
	Turkey Point 4	FL	P	Rail	52	86
Edwin I. Hatch	Edwin I. Hatch 1	GA	B	Rail	116	288
Vogtle	Vogtle 1	GA	P	Rail	205	283
Duane Arnold	Duane Arnold	IA	B	Rail	57	129
Braidwood	Braidwood 1	IL	P	Rail	94	162

Table 2-3. Shipments of commercial SNF, mostly rail scenario[a]. (2 of 3)

Site	Reactor	State	Fuel type	Cask	Proposed Action 2010-2033	Modules 1 and 2 2010-2048
Byron	Byron 1	IL	P	Rail	101	159
Clinton	Clinton 1	IL	B	Rail	59	87
Dresden/Morris	Dresden 1	IL	B	Rail	11	11
	Dresden 2	IL	B	Rail	83	158
	Dresden 3	IL	B	Rail	89	160
	Morris[d]	IL	B	Rail	43	43
	Morris[d]	IL	P	Rail	15	15
LaSalle	LaSalle 1	IL	B	Rail	101	305
Quad Cities	Quad Cities 1	IL	B	Rail	172	329
Zion	Zion 1	IL	P	Rail	93	93
Wolf Creek	Wolf Creek 1	KS	P	Rail	63	97
River Bend	River Bend 1	LA	B	Rail	57	87
Waterford	Waterford 3	LA	P	Rail	66	93
Pilgrim	Pilgrim 1	MA	B	Rail	24	18
	Pilgrim 1	MA	B	Truck	154	394
Yankee-Rowe	Yankee-Rowe 1	MA	P	Rail	15	15
Calvert Cliffs	Calvert Cliffs 1	MD	P	Rail	169	320
Maine Yankee	Maine Yankee	ME	P	Rail	55	55
Big Rock Point	Big Rock Point	MI	B	Rail	7	7
D. C. Cook	D. C. Cook 1	MI	P	Rail	149	268
Fermi	Fermi 2	MI	B	Rail	61	91
Palisades	Palisades	MI	P	Rail	70	122
Monticello	Monticello	MN	B	Rail	32	19
	Monticello	MN	B	Truck	8	250
Prairie Island	Prairie Island 1	MN	P	Rail	103	205
Callaway	Callaway 1	MO	P	Rail	71	101
Grand Gulf	Grand Gulf 1	MS	B	Rail	80	215
Brunswick	Brunswick 1	NC	P	Rail	14	14
	Brunswick 2	NC	P	Rail	12	12
	Brunswick 1	NC	B	Rail	78	142
	Brunswick 2	NC	B	Rail	78	140
Shearon Harris	Shearon Harris 1	NC	P	Rail	89	146
	Shearon Harris	NC	B	Rail	43	43
McGuire	McGuire 1	NC	P	Rail	83	164
	McGuire 2	NC	P	Rail	89	173
Cooper Station	Cooper Station	NE	B	Rail	42	124
Fort Calhoun	Fort Calhoun	NE	P	Rail	61	120
Seabrook	Seabrook 1	NH	P	Rail	49	80
Oyster Creek	Oyster Creek 1	NJ	B	Rail	64	110
Salem/Hope Creek	Salem 1	NJ	P	Rail	59	101
	Salem 2	NJ	P	Rail	54	108
	Hope Creek	NJ	B	Rail	67	105
James A. FitzPatrick/ Nine Mile Point	FitzPatrick	NY	B	Rail	60	121
	Nine Mile Point 1	NY	B	Rail	72	99
	Nine Mile Point 2	NY	B	Rail	65	105
Ginna	Ginna	NY	P	Rail	36	22
	Ginna	NY	P	Truck	91	297

Table 2-3. Shipments of commercial SNF, mostly rail scenario[a]. (3 of 3)

Site	Reactor	State	Fuel type	Cask	Proposed Action 2010-2033	Modules 1 and 2 2010-2048
Indian Point	Indian Point 1	NY	P	Truck	40	40
	Indian Point 2	NY	P	Rail	35	34
	Indian Point 2	NY	P	Truck	150	471
	Indian Point 3	NY	P	Rail	22	19
	Indian Point 3	NY	P	Truck	145	482
Davis-Besse	Davis-Besse 1	OH	P	Rail	64	140
Perry	Perry 1	OH	B	Rail	42	67
Trojan	Trojan	OR	P	Rail	33	33
Beaver Valley	Beaver Valley 1	PA	P	Rail	52	94
	Beaver Valley 2	PA	P	Rail	41	76
Limerick	Limerick 1	PA	B	Rail	148	216
Peach Bottom	Peach Bottom 2	PA	B	Rail	82	157
	Peach Bottom 3	PA	B	Rail	80	157
Susquehanna	Susquehanna 1	PA	B	Rail	201	460
Three Mile Island	Three Mile Island 1	PA	P	Rail	57	97
Catawba	Catawba 1	SC	P	Rail	70	109
	Catawba 2	SC	P	Rail	69	107
Oconee	Oconee 1	SC	P	Rail	208	353
	Oconee 3	SC	P	Rail	64	129
H. B. Robinson	H. B. Robinson 2	SC	P	Rail	82	128
Summer	Summer 1	SC	P	Rail	46	113
Sequoyah	Sequoyah	TN	P	Rail	95	275
Watts Bar	Watts Bar 1	TN	P	Rail	26	74
Comanche Peak	Comanche Peak 1	TX	P	Rail	154	250
South Texas	South Texas 1	TX	P	Rail	58	104
	South Texas 2	TX	P	Rail	57	105
North Anna	North Anna 1	VA	P	Rail	143	289
Surry	Surry 1	VA	P	Rail	197	330
Vermont Yankee	Vermont Yankee 1	VT	B	Rail	73	137
Columbia Generating Station	Columbia Generating Station	WA	B	Rail	77	159
Kewaunee	Kewaunee	WI	P	Rail	51	87
La Crosse	La Crosse	WI	B	Rail	5	5
Point Beach	Point Beach	WI	P	Rail	130	213
Total BWR[b]					**2,701**	**5,402**
Total PWR[c]					**5,596**	**10,709**

a. Source: DIRS 157206-CRWMS M&O 2000, all.
b. B = boiling-water reactor (BWR).
c. P = pressurized-water reactor (PWR).
d. Morris is a storage facility located close to the three Dresden reactors.

2.5.2 DEPARTMENT OF ENERGY SPENT NUCLEAR FUEL

The number of DOE SNF shipments was estimated based on information provided by the DOE Spent Nuclear Fuel Program (DIRS 104778-Jensen 1998, all). The DOE SNF shipment data are presented in Attachment 2A.

As discussed above, under the Proposed Action, 2,333 MTHM of DOE SNF would be shipped to Yucca Mountain. For Modules 1 and 2, a total of approximately 2,500 MTHM would be shipped. Table 2-4 lists the DOE SNF types and MTHM. Table 2-5 lists the total number of canisters (truck shipments) of DOE SNF by canister size and site. Table 2-6 presents the total number of rail shipments from each site by canister size and site. Both Table 2-5 and 2-6 represent the total DOE SNF (2,500 MTHM) to be shipped to Yucca Mountain for Modules 1 and 2.

To estimate the number of canisters for the Proposed Action, the numbers of canisters in Table 2-5 were adjusted by the ratio of metric tons to be shipped for the Proposed Action (2,333 MTHM) to the total metric tons of DOE SNF (2,500 MTHM), a factor of approximately 0.93. Tables 2-7 and 2-8 present the number of canisters for the Proposed Action and Modules 1 and 2 for the mostly legal-weight truck and mostly rail scenarios. One of the entries in Tables 2-7 and 2-8 is the fuel category/canister size, which presents the transportation mode (truck (T) or rail (R)) the fuel type (D1 is DOE SNF type 1 in Table 2 4), and the canister size (17– or 24–inch). Table 2-9 summarizes DOE SNF shipments from each site for the Proposed Action and the inventory modules. The shipment numbers of DOE SNF for the Proposed Action were estimated based on:

- A total of 2,500 MTHM of DOE SNF from 16 different categories.
- A factor of 0.93 (2,300/2,500), which is the ratio of the DOE SNF inventory to be shipped under the Proposed Action (2,333 MTHM) to the total amount of DOE SNF inventory that would be shipped under Modules 1 and 2 (2,500 MTHM).
- All naval SNF (~ 62 MTHM) would be delivered under the Proposed Action.
- Accounting for the naval SNF that would be shipped, approximately 93 percent of the total from each category (Table 2-4) would be shipped under the Proposed Action.

Table 2-4. DOE SNF quantities.

Category	SNF Type	MTHM
1	U Metal	2,122.263
2	U-Zr	0.040
3	Uranium-Mo alloy	3.767
4	Uranium oxide	98.680
5	Uranium oxide-disrupted cladding	87.021
6	U-Al alloy	8.740
7	U Si	11.551
8	High-integrity U-Th carbide	24.667
9	Low-integrity U-Th carbide	1.663
10	U and U-Pu carbide	0.153
11	Mixed oxide	12.320
12	U-Th oxide	49.631
13	U-Zr hydride	2.028
14	Sodium-bonded	(a)
15	Navy fuel	(b)
16	Miscellaneous	10.729
Total		2,498

a. To be treated and converted to HLW.
b. 65 MTHM.

Table 2-5. Number of canisters (truck shipments) of DOE SNF.[a]

DOE SNF Category	Number of Canisters/Truck Shipments						
	Hanford		INEEL		Savannah River	Navy (rail shipments)	
	17-inch	25.3-inch	17-inch	24-inch	17-inch	Short SNF Canister	Long SNF Canister
1		440	6		9		
2			8				
3			70				
4	14	20	179	16			
5	1		406		425		
6					750		
7					225		
8			503				
9			60				
10	2		3				
11	324		43				
12			24	47			
13	3		97				
15						200	100
16	5		39		2		
Total	349	460	1,438	63	1,411	200	100
	809		**1,501**		**1,411**	**300**	

a. Sources: Jensen (104778-1998, all); 148240-Dirkmaat (1998, all).

Table 2-6. Number of rail shipments of DOE SNF.[a]

DOE SNF Category	Number of Rail Shipments						
	Hanford		INEEL		Savannah River	Navy	
	17-inch	25.3-inch	17-inch	24-inch	17-inch	Short SNF Canister	Long SNF Canister
1		110	1		1		
2			1				
3			8				
4	2	5	20	4			
5	1		46		48		
6					84		
7					25		
8[b]			56				
9			7				
10	1		1				
11	36		5				
12			3	12			
13	1		11				
15						200	100
16	1		5		1		
Total	42	115	164	16	159	200	100
	157		**180**		**159**	**300**	

a. Sources: Jensen (DIRS 104778 – 1998, all); DIRS 148240-Dirkmaat (1998, all).
b. Includes 38 shipments from Ft. St. Vrain.

Assumptions:

1. One 17-inch-diameter canister or one 24-inch-diameter canister per truck cask.
2. Nine 17-inch-diameter canisters per rail cask.
3. Four 24-inch-diameter canisters per rail cask.

Table 2-7. Shipments of DOE SNF for the mostly legal-weight truck case.

Site	Fuel Category/ Canister Size	Proposed Action	Module1	Module2
Hanford	TD10-17	2	2	2
	TD11-17	301	324	324
	TD1-24	410	440	440
	TD13-17	3	3	3
	TD16-17	5	5	5
	TD4-17	14	14	14
	TD4-24	18	20	20
	TD5-17	1	1	1
Hanford – Total		**754**	**809**	**809**
INEEL	TD10-17	3	3	3
	TD11-17	40	43	43
	TD1-17	6	6	6
	TD12-17	23	24	24
	TD12-24	44	47	47
	TD13-17	90	97	97
	TD16-17	36	39	39
	TD2-17	8	8	8
	TD3-17	65	70	70
	TD4-17	167	179	179
	TD4-24	15	16	16
	TD5-17	378	406	406
	TD8-17	157	169	169
	TD9-17	56	60	60
INEEL – Total		**1,088**	**1,167**	**1,167**
Ft St. Vrain	TD8-17	312	334	334
Savannah River	TD1-17	9	9	9
	TD16-17	2	2	2
	TD5-17	396	425	425
	TD6-17	699	750	750
	TD7-17	210	225	225
Savannah River – Total		**1,316**	**1,411**	**1,411**
Total - All DOE SNF		**3,470**	**3,721**	**3,721**

Table 2-8. Shipments of DOE SNF for the mostly rail case.

Site	Fuel Category/ Canister Size	Proposed Action	Module1	Module2
Hanford	RD10-17	1	1	1
	RD11-17	34	36	36
	RD1-24	102	110	110
	RD13-17	1	1	1
	RD16-17	1	1	1
	RD4-17	2	2	2
	RD4-24	5	5	5
	RD5-17	1	1	1
Hanford – Total		**147**	**157**	**157**
INEEL	RD10-17	1	1	1
	RD11-17	5	5	5
	RD1-17	1	1	1
	RD12-17	3	3	3
	RD12-24	11	12	12
	RD13-17	11	11	11
	RD16-17	5	5	5
	RD2-17	1	1	1
	RD3-17	8	8	8
	RD4-17	18	20	20
	RD4-24	4	4	4
	RD5-17	41	46	46
	RD8-17	17	18	18
	RD9-17	7	7	7
INEEL Navy	RD15-N	300	300	355
INEEL – Total		**133**	**142**	**142**
Ft St. Vrain – Total	RD8-17	**36**	**38**	**38**
Savannah River	RD1-17	1	1	1
	RD16-17	1	1	1
	RD5-17	45	48	48
	RD6-17	78	84	84
	RD7-17	24	25	25
Savannah River – Total		**149**	**159**	**159**
Total DOE SNF		**765**	**796**	**796**

Table 2-9. Number of DOE SNF shipments for the Proposed Action and Modules 1 and 2.

	Proposed Action			
	Shipments			
	Mostly Truck		**Mostly Rail**	
Site	**Truck**	**Rail**	**Truck**	**Rail**
INEEL	1,088	300	0	433
Hanford	754	0	0	147
SRS	1,316	0	0	149
Ft. St. Vrain	312	0	0	36
Total	**3,470**	**300**		**765**
	Modules 1 and 2			
	Shipments			
	Mostly Truck		**Mostly Rail**	
Site	**Truck**	**Rail**	**Truck**	**Rail**
INEEL	1,167	300		442
Hanford	809	0	0	157
SRS	1,411	0	0	159
Ft. St. Vrain	334	0	0	38
Total	**3,721**	**300**		**796**

2.5.3 HIGH-LEVEL RADIOACTIVE WASTE

The number of HLW shipments was estimated based on data provided by DOE. Specifically, in addition to radionuclide information, DOE provided the number of canisters of HLW at each site. The assumption in the Throughput Study (DIRS 100265-CRWMS M&O 1997, all) of one HLW canister per truck shipment and five per rail shipment was then used to estimate the number of shipments (see Table 2-10). Detailed descriptions of the HLW that would be shipped to Yucca Mountain are presented in Section 5.3 of this document.

Table 2-10. Number of HLW shipments for the Proposed Action and Modules 1 and 2.

	Shipments of HLW[a]			
	Proposed Action			
	Mostly Truck		**Mostly Rail**	
Site	**Truck[a]**	**Rail**	**Truck**	**Rail**
Hanford	1,960	0	0	392
SRS	6,055	0	0	1,211
West Valley	300	0	0	60
Total	8,315			1,663
	Module 1			
	Mostly Truck		**Mostly Rail**	
Site	**Truck**	**Rail**	**Truck**	**Rail**
Hanford	14,500	0	0	2,900
SRS	6,188	0	0	1,238
INEEL	1,190	0	0	238
ANL-W	102	0	0	22
West Valley	300	0	0	60
Total	22,280			4,458

a. Indicates the total number of canisters of HLW from each site.

2.5.4 GTCC AND SPAR WASTE SHIPMENTS

Reasonably foreseeable future actions could include shipments of greater –than-Class-C (GTCC) and Special-Performance-Assessment-Required (SPAR) waste to the Yucca Mountain Repository. Commercial nuclear power plants, research reactors, radioisotope manufacturers, and other manufacturing and research institutions generate low-level radioactive waste that exceeds the Nuclear Regulatory Commission Class C shallow-land-burial disposal limits. In addition to DOE-held material, there are three other sources or categories of GTCC low-level radioactive waste:

- Nuclear utilities
- Sealed sources
- Other generators

The "other generators" of GTCC low-level radioactive waste are categorized into seven business types:

- Carbon-14 user
- Industrial research and development
- Irradiation laboratory
- Fuel fabricator
- University reactor
- Sealed-source manufacturer
- Nonmedical academic institution

The activities of nuclear electric utilities and other radioactive waste generators to date have produced relatively small quantities of GTCC low-level radioactive waste (Table 2-11). As the utilities take their reactors out of service and decommission them, they could generate more waste of this type.

Table 2-11. Commercial nuclear power plant GTCC shipments and projections (m^3)[a]. (1 of 3)

Unit name	Reactor Type	Projected Volume (m^3)	Volume/2	Truck Shipments	Volume/10	Rail Shipments
Arkansas Nuclear 1	PWR-B&W	10.3	5.2	6	1.03	2
Arkansas Nuclear 2	PWR-CE	21.1	10.6	11	2.11	3
Beaver Valley 1	PWR-W	10.8	5.4	6	1.08	2
Beaver Valley 2	PWR-W	10.8	5.4	6	1.08	2
Big Rock Point	BWR	8.9	4.5	5	0.89	1
Braidwood 1	PWR-W	10.8	5.4	6	1.08	2
Braidwood 2	PWR-W	10.8	5.4	6	1.08	2
Browns Ferry 1	BWR	8.9	4.5	5	0.89	1
Browns Ferry 2	BWR	8.9	4.5	5	0.89	1
Browns Ferry 3	BWR	8.9	4.5	5	0.89	1
Brunswick 1	BWR	8.9	4.5	5	0.89	1
Brunswick 2	BWR	8.9	4.5	5	0.89	1
Byron 1	PWR-W	10.8	5.4	6	1.08	2
Byron 2	PWR-W	10.8	5.4	6	1.08	2
Callaway	PWR-W	10.8	5.4	6	1.08	2
Calvert Cliffs 1	PWR-CE	21.1	10.6	11	2.11	3
Calvert Cliffs 2	PWR-CE	21.1	10.6	11	2.11	3

Table 2-11. Commercial nuclear power plant GTCC shipments and projections (m^3)[a]. (2 of 3)

Unit name	Reactor Type	Projected Volume (m^3)	Volume/2	Truck Shipments	Volume/10	Rail Shipments
Catawba 1	PWR-W	10.8	5.4	6	1.08	2
Catawba 2	PWR-W	10.8	5.4	6	1.08	2
Clinton	BWR	8.9	4.5	5	0.89	1
Comanche Peak 1	PWR-W	10.8	5.4	6	1.08	2
Comanche Peak 2	PWR-W	10.8	5.4	6	1.08	2
Cooper Station	BWR	8.9	4.5	5	0.89	1
Crystal River 3	PWR-B&W	10.3	5.2	6	1.03	2
Davis-Besse	PWR-B&W	10.3	5.2	6	1.03	2
Diablo Canyon 1	PWR-W	10.8	5.4	6	1.08	2
Diablo Canyon 2	PWR-W	10.8	5.4	6	1.08	2
Donald C. Cook 1	PWR-W	10.8	5.4	6	1.08	2
Donald C. Cook 2	PWR-W	10.8	5.4	6	1.08	2
Dresden 1	BWR	8.9	4.5	5	0.89	1
Dresden 2	BWR	8.9	4.5	5	0.89	1
Dresden 3	BWR	8.9	4.5	5	0.89	1
Duane Arnold 1	BWR	8.9	4.5	5	0.89	1
Fermi 2	BWR	8.9	4.5	5	0.89	1
Fort Calhoun 1	PWR-CE	21.1	10.6	11	2.11	3
Grand Gulf 1	BWR	8.9	4.5	5	0.89	1
Haddam Neck	PWR-W	10.8	5.4	6	1.08	2
Hatch 1	BWR	8.9	4.5	5	0.89	1
Hatch 2	BWR	8.9	4.5	5	0.89	1
Hope Creek	BWR	8.9	4.5	5	0.89	1
Humboldt Bay	BWR	8.9	4.5	5	0.89	1
H.B Robinson 2	PWR-W	10.8	5.4	6	1.08	2
Indian Point 1	BWR	8.9	4.5	5	0.89	1
Indian Point 2	PWR-W	10.8	5.4	6	1.08	2
Indian Point 3	PWR-W	10.8	5.4	6	1.08	2
James A. Fitzpatrick	BWR	8.9	4.5	5	0.89	1
Joseph M. Farley 1	PWR-W	10.8	5.4	6	1.08	2
Joseph M. Farley 2	PWR-W	10.8	5.4	6	1.08	2
Kewaunee	PWR-W	10.8	5.4	6	1.08	2
Lacrosse	BWR	8.9	4.5	5	0.89	1
LaSalle 1	BWR	8.9	4.5	5	0.89	1
LaSalle 2	BWR	8.9	4.5	5	0.89	1
Limerick 1	BWR	8.9	4.5	5	0.89	1
Limerick 2	BWR	8.9	4.5	5	0.89	1
Maine Yankee	PWR-CE	21.1	10.6	11	2.11	3
McGuire 1	PWR-W	10.8	5.4	6	1.08	2
McGuire 2	PWR-W	10.8	5.4	6	1.08	2
Millstone 1	BWR	8.9	4.5	5	0.89	1
Millstone 2	PWR-CE	21.1	10.6	11	2.11	3
Millstone 3	PWR-W	10.8	5.4	6	1.08	2
Monticello	BWR	8.9	4.5	5	0.89	1
Nine Mile Point 1	BWR	8.9	4.5	5	0.89	1
Nine Mile Point 2	BWR	8.9	4.5	5	0.89	1
North Anna 1	PWR-W	10.8	5.4	6	1.08	2
North Anna 2	PWR-W	10.8	5.4	6	1.08	2
Oconee 1	PWR-B&W	10.3	5.2	6	1.03	2
Oconee 2	PWR-B&W	10.3	5.2	6	1.03	2
Oconee 3	PWR-B&W	10.3	5.2	6	1.03	2
Oyster Creek	BWR	8.9	4.5	5	0.89	1

Table 2-11. Commercial nuclear power plant GTCC shipments and projections (m^3)[a]. (3 of 3)

Unit name	Reactor Type	Projected Volume (m^3)	Volume/2	Truck Shipments	Volume/10	Rail Shipments
Palisades	PWR-CE	21.1	10.6	11	2.11	3
Palo Verde 1	PWR-CE	21.1	10.6	11	2.11	3
Palo Verde 2	PWR-CE	21.1	10.6	11	2.11	3
Palo Verde 3	PWR-CE	21.1	10.6	11	2.11	3
Peach Bottom 2	BWR	8.9	4.5	5	0.89	1
Peach Bottom 3	BWR	8.9	4.5	5	0.89	1
Perry 1	BWR	8.9	4.5	5	0.89	1
Pilgrim 1	BWR	8.9	4.5	5	0.89	1
Point Beach 1	PWR-W	10.8	5.4	6	1.08	2
Point Beach 2	PWR-W	10.8	5.4	6	1.08	2
Prairie Island 1	PWR-W	10.8	5.4	6	1.08	2
Prairie Island 2	PWR-W	10.8	5.4	6	1.08	2
Quad Cities 1	BWR	8.9	4.5	5	0.89	1
Quad Cities 2	BWR	8.9	4.5	5	0.89	1
Rancho Seco	PWR-B&W	10.3	5.2	6	1.03	2
River Bend 1	BWR	8.9	4.5	5	0.89	1
Robert Ginna	PWR-W	10.8	5.4	6	1.08	2
Salem 1	PWR-W	10.8	5.4	6	1.08	2
Salem 2	PWR-W	10.8	5.4	6	1.08	2
San Onofre 1	PWR-W	10.8	5.4	6	1.08	2
San Onofre 2	PWR-CE	21.1	10.6	11	2.11	3
San Onofre 3	PWR-CE	21.1	10.6	11	2.11	3
Seabrook 1	PWR-W	10.8	5.4	6	1.08	2
Sequoyah 1	PWR-W	10.8	5.4	6	1.08	2
Sequoyah 2	PWR-W	10.8	5.4	6	1.08	2
Shearon Harris	PWR-W	10.8	5.4	6	1.08	2
Shoreham	BWR	0	0.0	0	0	0
South Texas 1	PWR-W	10.8	5.4	6	1.08	2
South Texas 2	PWR-W	10.8	5.4	6	1.08	2
St. Lucie 1	PWR-CE	21.1	10.6	11	2.11	3
St. Lucie 2	PWR-CE	21.1	10.6	11	2.11	3
Summer 1	PWR-W	10.8	5.4	6	1.08	2
Surry 1	PWR-W	10.8	5.4	6	1.08	2
Surry 2	PWR-W	10.8	5.4	6	1.08	2
Susquehanna 1	BWR	8.9	4.5	5	0.89	1
Susquehanna 2	BWR	8.9	4.5	5	0.89	1
Three Mile Island 1	PWR-B&W	10.3	5.2	6	1.03	2
Trojan	PWR-W	10.8	5.4	6	1.08	2
Turkey Point 3	PWR-W	10.8	5.4	6	1.08	2
Turkey Point 4	PWR-W	10.8	5.4	6	1.08	2
Vermont Yankee	BWR	8.9	4.5	5	0.89	1
Vogtle 1	PWR-W	10.8	5.4	6	1.08	2
Vogtle 2	PWR-W	10.8	5.4	6	1.08	2
Washington Nuclear 2	BWR	8.9	4.5	5	0.89	1
Waterford 3	PWR-CE	21.1	10.6	11	2.11	3
Watts Bar 1	PWR-W	10.8	5.4	6	1.08	2
Wolf Creek	PWR-W	10.8	5.4	6	1.08	2
Yankee-Rowe	PWR-W	10.8	5.4	6	1.08	2
Zion 1	PWR-W	10.8	5.4	6	1.08	2
Zion 2	PWR-W	10.8	5.4	6	1.08	2
Total		**1,347**		**742**		**210**

a. See Attachment 2A for basis for shipment numbers.

DOE SPAR low-level radioactive waste could include the following materials:

- Production reactor operating wastes
- Production and research reactor decommissioning wastes
- Non-fuel-bearing components of naval reactors
- Sealed radioisotope sources that exceed Class C limits for waste classification
- DOE isotope production-related wastes
- Research reactor fuel assembly hardware

The analysis estimated the number of shipments of GTCC and SPAR waste by assuming that 10 cubic meters (about 350 cubic feet) would be shipped in a rail cask and 2 cubic meters (about 71 cubic feet) would be shipped in a truck cask. Table 2-12 lists the number of commercial GTCC waste shipments in Inventory Module 2 for both truck and rail shipments. The shipments of GTCC waste from commercial utilities would originate among the commercial reactor sites. Typically, boiling-water reactors (BWRs) would ship a total of about 9 cubic meters (about 318 cubic feet) of GTCC waste per site, while pressurized-water reactors (PWRs) would ship about 20 cubic meters (about 710 cubic feet) per site. The impacts of transporting this waste were examined for each reactor site. The analysis assumed that sealed sources and GTCC waste identified as "other" would be shipped from the DOE SRS (Table 2-12).

The analysis assumed DOE SPAR waste would be shipped from the four DOE sites listed in Table 2-13. For the Yucca Mountain FEIS analysis, the SPAR wastes from naval reactors and Argonne East would be shipped from INEEL and are included in the shipments from INEEL listed in Table 2-13. Similarly, the SPAR waste from ORNL would be shipped from the SRS.

Table 2-12. Commercial GTCC waste shipments.

Category	Volume (cubic meters)[a, b]	Truck	Rail
Commercial utilities	1,350	742	210[c]
Sealed sources	240	121	25
Other	470	233	47
Total	**2,060**	**1,096**	**282**

a. Source: DIRS 101798–DOE 1994, all.
b. To convert cubic meters to cubic feet, multiply by 35.314.
c. This number does not equal 135 or 1,350/10 because a number of the commercial reactor sites have a volume of waste slightly greater than a multiple of 10 cubic meters, which would result in an additional shipment.

Table 2-13. DOE SPAR waste shipments.

Generator site[a]	Volume (m^3)[b, c]	Rail	Truck
Hanford	20	2	10
INEEL	515	58	11 (55)[d]
SRS (ORNL)	2,932	294	1,466[c]
West Valley	550	56	276
Total	**4,018**	**410**	**1,763**

Abbreviations: INEEL = Idaho National Engineering and Environmental Laboratory; SRS = Savannah River Site; ORNL = Oak Ridge National Laboratory.
a. To convert cubic meters to cubic feet, multiply by 35.314.
b. Source: DIRS 104411–Picha 1998, all.
c. The 55 shipments represent naval SPAR waste shipped from the INEEL site.
d. SRS includes waste shipments delivered from ORNL.

In addition to the shipment data presented above, the transportation Microsoft Access database described in Appendix A provides the ability to query the database for specific information on shipments. For example, a query can be written to determine the number of shipments of all fuel types (or a specific fuel type) that originate or pass through a particular state. This type of query was used to determine, based on highway and rail routing, the number and direction of shipments entering the State of Nevada. Attachment 2A provides the results of a query to determine shipments through or originating in each state.

Table 2-14 lists the filenames and contents of each file contained in Attachment 2A, included on compact disk but not included in this section due to its length. These files are organized in folders by fuel or material type and contain the data used to estimate the shipment numbers for the Proposed Action and Modules 1 and 2. The file *Attachment 2A filenames.xls* in Attachment 2A contains a list of files in Attachment 2A, including directory, subdirectory, date, time, size, and filename.

Table 2-14. Filename key - Attachment 2A. (1 of 2)

File Name	Description
Files for Commercial SNF	
Ann_Pool_Ships_DWBI_ALL_TRUCK_FEIS	Shipments for the Mostly Legal-Weight Truck Scenario
Worksheets	
Title	**Description**
Info	Assumptions for Mostly Legal-Weight Truck Scenario – Case A was selected.
Case A_63KFEIS	Legal-weight truck commercial SNF shipments for 63,000 MTHM under the Proposed Action for the YM FEIS (with commercial SNF at DOE sites removed) YFF 10 (select 10-yr-old fuel if it is available and it does not exceed primary cask heat limit, else select 11,12,13...etc)
Case A_63K	Legal-weight truck commercial SNF shipments for 63,000 MTHM under the Proposed Action for the YM FEIS Case A - YFF 10 (select 10-yr-old fuel if it is available and it does not exceed primary cask heat limit, else select 11,12,13...etc)
Case B_63K	Legal-weight truck commercial SNF shipments for 63,000 MTHM under the Proposed Action for the YM FEIS Case B - Strict YFF 10 (select 10-yr-old fuel if available-switch to more robust cask if primary cask heat limit exceeded, then select 11,12,13...etc)
Case C_63K	Legal-weight truck commercial SNF shipments for 63,000 MTHM under the Proposed Action for the YM FEIS Case C - OFF (oldest fuel in pool selected first, then younger fuel)
Case A_105-DOE	Legal-weight truck commercial SNF shipments for 105,000 MTHM under the Proposed Action for the YM FEIS (with commercial SNF at DOE sites removed) YFF 10 (select 10-yr-old fuel if it is available and it does not exceed primary cask heat limit, else select 11,12,13...etc)
Case A_105	Legal-weight truck commercial SNF shipments for 105,000 MTHM under the Proposed Action for the YM FEIS Case A - YFF 10 (select 10-yr-old fuel if it is available and it does not exceed primary cask heat limit, else select 11,12,13...etc)
Case B_105	Legal-weight truck commercial SNF shipments for 105,000 MTHM under the Proposed Action for the YM FEIS Case B - Strict YFF 10 (select 10-yr-old fuel if available-switch to more robust cask if primary cask heat limit exceeded, then select 11,12,13...etc)
Case C_105	Legal-weight truck commercial SNF shipments for 105,000 MTHM under the Proposed Action for the YM FEIS Case C - OFF (oldest fuel in pool selected first, then younger fuel)
Ann_Pool_Ships_ DWBI_Casks_FEI S	Shipments for the Mostly Rail Scenario

Table 2-14. Filename key - Attachment 2A. (2 of 2)

Worksheets	
Title	**Description**
Info	Assumptions for Mostly Rail Scenario – Case A was selected.
Case A_63K	Rail commercial SNF shipments for 63,000 MTHM under the Proposed Action for the YM FEIS (with commercial SNF at DOE sites removed) YFF 10 (select 10-yr-old fuel if it is available and it does not exceed primary cask heat limit, else select 11,12,13...etc)
Case B_63K	Rail commercial SNF shipments for 63,000 MTHM under the Proposed Action for the YM FEIS Case B - Strict YFF 10 (select 10-yr-old fuel if available-switch to more robust cask if primary cask heat limit exceeded, then select 11,12,13...etc)
Case C_63K	Rail commercial SNF shipments for 63,000 MTHM under the Proposed Action for the YM FEIS Case C - OFF (oldest fuel in pool selected first, then younger fuel)
Case A_105-DOE	Rail commercial SNF shipments for 105,000 MTHM under the Proposed Action for the YM FEIS (with commercial SNF at DOE sites removed) YFF 10 (select 10-yr-old fuel if it is available and it does not exceed primary cask heat limit, else select 11,12,13...etc)
Case A_105	Rail commercial SNF shipments for 105,000 MTHM under the Proposed Action for the YM FEIS Case A - YFF 10 (select 10-yr-old fuel if it is available and it does not exceed primary cask heat limit, else select 11,12,13...etc)
Case B_105	Rail commercial SNF shipments for 105,000 MTHM under the Proposed Action for the YM FEIS Case B - Strict YFF 10 (select 10-yr-old fuel if available-switch to more robust cask if primary cask heat limit exceeded, then select 11,12,13...etc)
Case C_105	Rail commercial SNF shipments for 105,000 MTHM under the Proposed Action for the YM FEIS Case C - OFF (oldest fuel in pool selected first, then younger fuel)
DOE SNF	
DOE SNF Shipment Basis_FEIS_Rev5	DOE SNF Shipments for the Mostly Legal-Weight Truck and Mostly Rail Scenarios
Worksheets	
Title	**Description**
Radionuclide Data	Radionuclide data for the 16 DOE SNF categories decayed to the year 2010.
Mostly Truck - DOE SNF	DOE SNF shipments for the mostly legal-weight truck scenario for the Proposed Action and Modules 1 and 2
Mostly Rail – DOE SNF	DOE SNF shipments for the mostly rail scenario for the Proposed Action and Modules 1 and 2
DOE SNF Summary	Summary of DOE SNF shipments for the mostly legal-weight truck and mostly rail scenarios for the Proposed Action and Modules 1 and 2.
Commercial GTCC	
Comm GTCC	**Commercial GTCC Waste Volumes**
Worksheets	
Title	**Description**
Commercial GTCC Volumes	Commercial GTCC volumes at commercial utility generator sites.

3.0 ROUTING

3.1 National Transportation Routing

3.1.1 INTRODUCTION

This section presents the national transportation routing analysis used in the transportation risk assessment for the Yucca Mountain FEIS.

3.1.2 METHOD

In order to assess the impacts of radioactive materials transportation, the characteristics of transportation routes between the origin of the shipment and its destination must be estimated. These route characteristics are quantities such as distance, population density, and weighted population density. Often, population density is binned into three zones-rural, suburban, and urban-where rural is defined as an area with a density of less than 139 people per square mile, suburban is defined as an area with a density between 139 and 3,326 people per square mile, and urban is defined as an area with a density greater than 3,326 people per square mile (DIRS 104780-Johnson et al. 1993, all; DIRS 104781-Johnson et al. 1993, all). Typically, the distance traveled within each population zone is estimated, as is the total distance. In addition, these quantities may be estimated on a state-specific level.

Highway and rail routes were analyzed using the routing computer codes HIGHWAY (DIRS 104780-Johnson et al. 1993, all) and INTERLINE (DIRS 104781-Johnson et al. 1993, all). Route characteristics include total shipment distance between each origin and destination; the distances traveled in rural, suburban, and urban population density zones; and the weighted population densities in these population density zones. Appendix H presents a routing analysis using WebTRAGIS (DIRS 157136, Johnson and Michelhaugh, 2001, all) and 2000 Census data.

The HIGHWAY computer code estimates highway routes for transporting radioactive materials within the United States and Canada. The HIGHWAY database contains over 386,000 kilometers (240,000 miles) of interstate highways, U.S. highways, state highways, turnpikes, county roads, and local roads. The database contains more than 20,000 highway segments (known as links) and 13,000 intersections (known as nodes), including nodes for many U.S. Nuclear Regulatory Commission and Agreement State-licensed facilities, DOE nuclear facilities, several nuclear facilities in Canada, and airports.

Routes are estimated by minimizing the total impedance of a route, which is a function of distance and driving time between the origin and destination. HIGHWAY also can estimate routes that maximize the use of interstate highways. This feature allows the user to estimate routes for transport of highway-route-controlled quantity shipments (e.g., SNF and HLW), based on U.S. Department of Transportation regulations contained in 49 CFR 397, Subpart D, Routing of Class 7 (Radioactive) Materials. Routes generated using these regulations are sometimes referred to as HM-164 routes, after the U.S. Department of Transportation docket number that contained the routing regulations, Radioactive Materials; Routing and Driver Training Requirements (46 FR 5298-5318). These routes follow interstate highways, use interstate bypasses or beltways around cities, and use state-designated preferred routes. The routes estimated in this analysis conform to applicable guidelines and regulations; therefore, they represent routes that could be used. However, they may not be the actual routes used in the future. HIGHWAY has been updated periodically to reflect current road conditions, and it has been validated (DIRS 101845-Maheras and Pippen 1995, Chapter 2) and benchmarked against reported mileage and observations of commercial truck firms.

Highway routes were estimated from 81 facilities at 77 sites to the Yucca Mountain repository (Table 3-1). The following eight highway routing cases were analyzed:

1. Highway routes using I-15, the northern, western, and southern beltway around Las Vegas, and U.S. 95 to Yucca Mountain. The northern, western, and southern beltway around Las Vegas is referred to as I-215 in the HIGHWAY computer code.
2. Highway routes using I-15 to U.S. 95 in Las Vegas to Yucca Mountain.
3. Highway routes using I-15 from Barstow, California, to NV 160 at Arden, Nevada, to U.S. 95 to Yucca Mountain.
4. Highway routes using I-15 from Barstow, California, to CA 127 at Baker, California, to NV 373 to U.S. 95 to Yucca Mountain.
5. Highway routes using U.S. 95 from Needles, California, to NV 164 at Searchlight, Nevada, to I-15 at Nipton, California, to CA 127 at Baker, California, to NV 373 to U.S. 95 to Yucca Mountain.
6. Highway routes using U.S. 95 from Needles, California, to NV 164 at Searchlight, Nevada, to I-15 at Nipton, California, to NV 160 at Arden, Nevada, to U.S. 95 to Yucca Mountain.
7. Highway routes using U.S. 93 alternate from Wendover, Utah, to U.S. 93 at Lages, Nevada, to U.S. 6 at Ely, Nevada, to U.S. 95 at Tonopah, Nevada, to Yucca Mountain.
8. Highway routes using U.S. 93 alternate from Wendover, Utah, to U.S. 93 at Lages, Nevada, to U.S. 6 at Ely, Nevada, to NV 318 at Preston, Nevada, to U.S. 93 at Hiko, Nevada, to I-15 at Garnet, Nevada, to the northern beltway around Las Vegas to U.S. 95 to Yucca Mountain.

Each of these highway routing options, which may have different entry points in Nevada, has the potential to affect routing nationally. A comparison of impacts in Nevada and nationally for each option above indicated only minor differences in impacts. In all cases, Interstate-70 west of Denver, Colorado, was blocked, to comply with the radioactive material routing restrictions contained in Transportation of Hazardous Materials: *Designated, Preferred, and Restricted Routes* (65 FR 75771-75816). In addition, according to Title 24, Agency 30, Chapter 61, Section 30 (24 VAC 30-61-30) of the Virginia Administrative Code, there are no restrictions on hazardous material transportation through the Big Walker Mountain Tunnel and the East River Mountain Tunnel on Interstate 77, so long as the shipments comply with Federal regulations. Therefore, the tunnel restrictions listed in 65 FR 75813 for Interstate 77 in Virginia were not used in the routing analysis. According to the Code of Maryland Regulations, Title 11, Subtitle 7, Chapter 1, Regulation 5 (11.07.01.05), the hazardous material routing restriction listed in 65 FR 75790 for Interstate 95 in Maryland is actually a provision requiring notification and permission, so the restriction for Interstate 95 in Maryland was not used in the routing analysis. According to the Ohio Administrative Code, Chapter 4901:2-8, the routing designations for interstate highways in northern Ohio listed in 65 FR 75803-75804 are for nonradioactive hazardous material, not radioactive material, so the restrictions for interstate highways in northern Ohio were not used in the routing analysis. Table 3-2 lists link and node deletions for each of these cases.

Table 3-1. Highway route origins.

Origin	State	Origin	State
Browns Ferry NP	AL	Callaway NP	MO
Farley NP	AL	Cooper NP	NE
Palo Verde NP	AZ	Fort Calhoun NP	NE
Arkansas NP	AR	Seabrook NP	NH
Diablo Canyon NP	CA	Hope Creek NP	NJ
Humboldt Bay NP	CA	Oyster Creek NP	NJ
Rancho Seco NP	CA	Salem NP	NJ
San Onofre NP	CA	Fitzpatrick NP	NY
Ft St Vrain NP	CO	Ginna NP	NY
Conn Yankee NP	CT	Indian Point NP	NY
Millstone NP	CT	Nine Mile Pnt NP	NY
Crystal River NP	FL	West Valley NP	NY
St Lucie NP	FL	Brunswick NP	NC
Turkey Point NP	FL	Harris NP	NC
Hatch NP	GA	Mcguire NP	NC
Vogtle NP	GA	Davis-Besse NP	OH
INEEL Chem Plt	ID	Perry NP	OH
Argonne West	ID	Trojan NP	OR
Braidwood NP	IL	Beaver Valley NP	PA
Byron NP	IL	Limerick NP	PA
Clinton NP	IL	Peach Bottom NP	PA
Dresden NP	IL	Susquehanna NP	PA
G E Repro Plnt	IL	Three Mile Is NP	PA
La Salle NP	IL	Catawba NP	SC
Quad Cities NP	IL	Oconee NP	SC
Zion NP	IL	Robinson NP	SC
Arnold NP	IA	SRS Site H	SC
Wolf Creek NP	KS	Summer NP	SC
River Bend NP	LA	Sequoyah NP	TN
Waterford NP	LA	Watts Bar NP	TN
Maine Yankee NP	ME	Comanche Peak NP	TX
Calvert Cliffs NP	MD	South Texas NP	TX
Pilgrim NP	MA	Vermont Yankee NP	VT
Yankee-Rowe NP	MA	North Anna NP	VA
Big Rock Point NP	MI	Surry NP	VA
Cook NP	MI	Hanford (WYE BARRICADE)	WA
Fermi NP	MI	WNP 1;2;4 NP	WA
Palisades NP	MI	Kewaunee NP	WI
Monticello NP	MN	La Crosse BWR NP	WI
Prairie Island NP	MN	Point Beach NP	WI
Grand Gulf NP	MS		

Note: For all origins, the destination was Yucca Mountain, Nevada.

Table 3-2. Link and node deletions for highway routes.

Case	Link Deletions	Node Deletions
1	No link deletions required.	COUTI70 LOMACRES, CO DENVER N I25 I70, CO
2	N. Las Vegas NE I15 x215 → Las Vegas NW I215 U95 N. Las Vegas N I15 x48 → Las Vegas NW U95B S573 Las Vegas W U95 U95B → VGT Airport Las Vegas S I15 I 215 → Las Vegas NW I215 U95	COUTI70 LOMACRES, CO DENVER N I25 I70, CO
3	No link deletions required.	COUTI70 LOMACRES, CO DENVER N I25 I70, CO CANVI15 NIPTSLOA, NV AZNVI15 LITTOVER, NV
4	No link deletions required.	COUTI70 LOMACRES, CO DENVER N I25 I70, CO CANVI15 NIPTSLOA, NV AZNVI15 LITTOVER, NV
5	No link deletions required.	COUTI70 LOMACRES, CO DENVER N I25 I70, CO AZNVI15 LITTOVER, NV
6	No link deletions required.	COUTI70 LOMACRES, CO DENVER N I25 I70, CO AZNVI15 LITTOVER, NV
7	No link deletions required.	COUTI70 LOMACRES, CO DENVER N I25 I70, CO YERMO, CA AZNVI15 LITTOVER, NV
8	No link deletions required.	COUTI70 LOMACRES, CO DENVER N I25 I70, CO YERMO, CA AZNVI15 LITTOVER, NV

The INTERLINE computer code is designed to simulate routing of the U.S. rail system. The INTERLINE database describes the U.S. railroad system and includes all rail lines except for industrial spurs. Inland and intracoastal waterways and deep water routes are also included in the database. The database contains more than 15,000 rail and barge segments (known as links) and more than 13,000 stations, interchange points, ports, and other locations (known as nodes). As with HIGHWAY, INTERLINE includes nodes for many U.S. Nuclear Regulatory Commission and Agreement State-licensed facilities, and DOE nuclear facilities.

Currently, there are no specific routing regulations for transporting radioactive material by rail. Therefore, the routes were estimated by minimizing a parameter called "total potential." Total potential is a calculated value used as a surrogate to measure overall preferability for a rail route. Total potential is a function of distance, mainline classification, and the number of railroads involved in making the shipment, which simulates the process used by railroads to transport commodities. INTERLINE has been updated periodically to reflect mergers, abandonments, and current track conditions, and has been validated (DIRS 101845-Maheras and Pippen 1995, Chapter 2) and benchmarked against reported mileage and observations of commercial rail firms.

Commercial railroad nodes in Nevada where analysis assumed Nevada implementing alternatives would connect to commercial railroads are as follows:

1. Apex (node 14763)
2. Beowawe (node 14791)
3. Caliente (node 14770)
4. Crestline (node 16344)
5. Dry Lake (node 16348)
6. Eccles (node 16347)
7. Jean (node 16328)

These destinations correspond to the likely locations of potential intermodal transfer (IMT) stations or origins of rail lines that would be built to the Yucca Mountain Repository. Table 3-3 contains the node numbers for the origins. In some cases, the nuclear facility did not have direct rail access. In these cases, a nearby rail node was chosen. Table 3-3 also contains the distance from the facility to the nearby rail node. In addition, if more than one railroad served an origin or destination, both options were run, and the minimum potential run was chosen. The INTERLINE rail network reflects the merger between the Southern Pacific and the Union Pacific. The combined Union Pacific and Southern Pacific network is denoted Union Pacific in the INTERLINE database. The INTERLINE rail network also reflects the granting of trackage rights to the Burlington Northern Santa Fe over Southern Pacific and Union Pacific track in northern Nevada as a part of the merger agreement. As a result of this granting of trackage rights to the Burlington Northern Santa Fe in northern Nevada, Beowawe may be served by either the Union Pacific or the Burlington Northern Santa Fe. Both the Union Pacific and Burlington Northern Santa Fe railroads were run for Beowawe, and the railroad yielding the minimum potential was used in the routing analysis (Table 3-4).

Barge routes from 17 sites that have waterway access and do not have direct rail access were also estimated. Routing for shipments of rail casks that would include a barge segment was done in multiple steps: (1) site to nearby barge node (Table 3-5); (2) rail node located at the barge node to end nodes in Nevada; and (3) end nodes in Nevada to Yucca Mountain using the ten implementing alternatives. Both the Union Pacific and Burlington Northern Santa Fe railroads were run for Beowawe, and the railroad yielding the minimum potential was used in the routing analysis (Table 3-6).

Table 3-3. Direct and indirect rail access nodes[a]. (1 of 2)

Direct Rail Access

Site	Rail Node	Site	Rail Node
Farley NP, AL	15449	Seabrook NP, NH	144
Palo Verde NP, AZ	12893	Fitzpatrick NP, NY	783
Arkansas NP, AR	9428	Nine Mile Point NP, NY	782
Humboldt Bay NP, CA	14307	West Valley, NY	851
Rancho Seco NP, CA	14389	Brunswick NP, NC	15354
San Onofre NP, CA	14711	Harris NP, NC	7425
Millstone NP, CT	557	Mcguire NP, NC	15329
Crystal River NP, FL	15426	Davis Besse NP, OH	14982
Hatch NP, GA	15395	Perry NP, OH	14963
Vogtle NP, GA	15392	Trojan NP, OR	16228
INEEL, ID (Scoville)	13336	Beaver Valley NP, PA	2093
Braidwood NP, IL	4108	Limerick NP, PA	1456
Byron NP, IL	15091	Susquehanna NP, PA	1656
Clinton NP, IL	4835	Three Mile Island NP, PA	1483
Dresden NP, IL	16819	Catawba NP, SC	15365
Morris, IL(Ge Repro Plnt)	16818	Robinson NP, SC	7655
La Salle NP, IL	15098	SRS, SC	15359
Quad Cities NP, IL	4276	Summer NP, SC	15364
Zion NP, IL	4083	Sequoyah NP, TN	15313
Arnold NP, IA	15674	Watts Bar NP, TN	15315
Wolf Creek NP, KS	15880	Comanche Peak NP, TX	16014
River Bend NP, LA	15514	South Texas NP, TX	15983
Waterford NP, LA	9005	Vermont Yankee NP, VT	252
Maine Yankee NP, ME	2582	North Anna NP, VA	15260
Cook NP, MI	5180	Hanford, WA	16212
Fermi NP, MI	15025	WNP 2 NP, WA	16213
Monticello NP, MN	15607	La Crosse NP, WI	15238
Prairie Island NP, MN	9802		

Indirect Rail Access

Site	Rail Access	Rail Node	Distance From Site To Rail Access (mi)
Browns Ferry NP, AL	Decatur Jct, AL	8765	34.4
Diablo Canyon NP, CA	San Luis Obispo, CA	16313	27.0
Fort St. Vrain NP, CO	Milliken, CO	13711	15.1
Haddam Neck NP, CT	Middletown, CT	571	10.3
St. Lucie NP, FL	Fort Pierce, FL	8471	14.5
Turkey Point NP, FL	Homestead, FL	8519	10.8
Calvert Cliffs NP, MD	Chalk Point, MD	2582	26.0
Pilgrim NP, MA	Plymouth, MA	397	5.4
Yankee-Rowe NP, MA	Hoosac Tunnel, MA	439	6.3
Big Rock Point NP, MI	Petoskey, MI	5508	12.4
Palisades NP, MI	Hartford, MI	5186	26.0
Grand Gulf NP, MS	Vicksburg, MS	8908	29.7
Callaway NP, MO	Fulton, MO	10462	11.5
Cooper NP, NE	Nebraska City, NE	11534	33.4
Fort Calhoun NP, NE	Blair, NE	11341	3.7
Hope Creek NP, NJ	Bridgeton, NJ	1365	31.7
Oyster Creek NP, NJ	Lakehurst, NJ	1306	17.7
Salem NP, NJ	Salem, NJ	2452	13.2
Ginna NP, NY	Webster, NY	14894	21.8
Indian Point NP, NY	Croton-On-Hudson, NY	1073	8.8
Peach Bottom NP, PA	York, PA	2432	36.6

Table 3-3. Direct and indirect rail access nodes[a]. (2 of 2)

Site	Rail Access	Rail Node	Distance From Site To Rail Access (mi)
Oconee NP, SC	Clemson, SC	7759	10.9
Surry NP, VA	Wakefield, VA	6044	46.7
Kewaunee NP, WI	Kewaunee, WI	5812	6.0
Point Beach NP, WI	Manitowoc, WI	5809	22.6

a. The destination rail nodes for all sites were Apex (node 14763), Beowawe (node 14791), Caliente (node 14770), Crestline (node 16344), Dry Lake (node 16348), Eccles (16347), and Jean (node 16328).

Table 3-4. Potentials for Beowawe rail routes[a]. (1 of 2)

Origin	State	Railroad	Potential	Railroad	Potential
Browns Ferry NP	AL	BNSF	2558.2	*UP*	2354.8
Farley NP	AL	BNSF	2979.1	*UP*	2796.5
Palo Verde NP	AZ	BNSF	1569.9	*UP*	1177.7
Arkansas NP	AR	BNSF	2089.2	*UP*	1452.9
Diablo Canyon NP	CA	BNSF	1011.1	*UP*	618.88
Humboldt Bay NP	CA	BNSF	2102.9	*UP*	1711.7
Rancho Seco NP	CA	BNSF	831.80	*UP*	405.52
San Onofre NP	CA	*BNSF*	790.05	UP	1173.6
Fort St. Vrain NP	CO	BNSF	1205.0	*UP*	660.32
Haddam Neck NP	CT	BNSF	3591.5	*UP*	3422.7
Millstone NP	CT	BNSF	3658.7	*UP*	3489.9
Crystal River NP	FL	BNSF	3100.5	*UP*	2897.2
St. Lucie NP	FL	BNSF	3586.6	*UP*	3450.9
Turkey Point NP	FL	BNSF	3430.6	*UP*	3227.2
Hatch NP	GA	BNSF	2920.7	*UP*	2725.6
Vogtle NP	GA	BNSF	2937.5	*UP*	2742.4
INEEL (Scoville)	ID	BNSF	1568.5	*UP*	473.92
Braidwood NP	IL	BNSF	2058.9	*UP*	1422.6
Byron NP	IL	BNSF	2217.2	*UP*	1966.6
Clinton NP	IL	BNSF	2182.5	*UP*	2103.7
Dresden NP Dock	IL	BNSF	2210.4	*UP*	2048.4
G E Repro Plnt	IL	BNSF	2204.0	*UP*	2042.0
La Salle NP	IL	*BNSF*	1484.8	UP	1884.8
Quad Cities NP	IL	*BNSF*	1497.3	UP	1897.3
Zion NP	IL	BNSF	2030.8	*UP*	1394.5
Arnold NP	IA	BNSF	2309.3	*UP*	1841.4
Wolf Creek NP	KS	BNSF	1850.3	*UP*	1214.0
River Bend NP	LA	BNSF	2662.8	*UP*	2607.5
Waterford NP	LA	BNSF	2361.4	*UP*	1888.3
Maine Yankee NP	ME	BNSF	3987.2	*UP*	3817.8
Calvert Cliffs NP	MD	BNSF	2874.9	*UP*	2708.6
Pilgrim NP	MA	BNSF	3787.5	*UP*	3618.7
Yankee-Rowe NP	MA	BNSF	3245.1	*UP*	3075.7
Big Rock Point NP	MI	BNSF	3382.8	*UP*	3214.0
Cook NP	MI	BNSF	2256.0	*UP*	2089.4
Fermi NP	MI	BNSF	2493.5	*UP*	2324.7
Palisades NP	MI	BNSF	2284.8	*UP*	2118.2
Monticello NP	MN	*BNSF*	1536.7	UP	1930.5
Prairie Island NP	MN	BNSF	2148.8	*UP*	1964.2
Grand Gulf NP	MS	BNSF	2385.2	*UP*	2260.9
Callaway NP	MO	BNSF	2083.5	*UP*	1874.3
Cooper NP	NE	BNSF	1694.3	*UP*	1058.0

Table 3-4. Potentials for Beowawe rail routes[a]. (2 of 2)

Origin	State	Railroad	Potential	Railroad	Potential
Fort Calhoun NP	NE	BNSF	1628.0	*UP*	991.68
Seabrook NP	NH	BNSF	3469.3	*UP*	3300.0
Hope Creek NP	NJ	BNSF	3314.9	*UP*	3145.6
Oyster Creek NP	NJ	BNSF	3276.8	*UP*	3107.4
Salem NP	NJ	BNSF	3341.4	*UP*	3172.1
Fitzpatrick NP	NY	BNSF	2812.1	*UP*	2645.8
Ginna NP	NY	BNSF	3207.3	*UP*	3038.5
Indian Point NP	NY	BNSF	2988.3	*UP*	2821.9
Nine Mile Point NP	NY	BNSF	2809.6	*UP*	2643.2
West Valley	NY	BNSF	3126.3	*UP*	2957.5
Brunswick NP	NC	BNSF	3675.0	*UP*	3484.3
Harris NP	NC	BNSF	3038.4	*UP*	2835.1
Mcguire NP	NC	BNSF	2953.5	*UP*	2786.9
Davis Besse NP	OH	BNSF	2419.9	*UP*	2248.0
Perry NP	OH	BNSF	2499.2	*UP*	2316.3
Trojan NP	OR	BNSF	1746.5	*UP*	1573.1
Beaver Valley NP	PA	BNSF	2571.9	*UP*	2405.5
Limerick NP	PA	BNSF	2841.7	*UP*	2658.8
Peach Bottom NP	PA	BNSF	2806.5	*UP*	2623.6
Susquehanna NP	PA	BNSF	3406.8	*UP*	3237.5
Three Mile Island NP	PA	BNSF	2791.1	*UP*	2608.2
Catawba NP	SC	BNSF	2873.3	*UP*	2678.2
Oconee NP	SC	BNSF	2790.8	*UP*	2595.7
Robinson NP	SC	BNSF	3012.0	*UP*	2808.7
SRS	SC	BNSF	3414.0	*UP*	3223.3
Summer NP	SC	BNSF	2819.7	*UP*	2624.6
Sequoyah NP	TN	BNSF	2610.5	*UP*	2415.4
Watts Bar NP	TN	BNSF	2582.5	*UP*	2387.4
Comanche Peak NP	TX	*BNSF*	2184.5	UP	2222.6
South Texas NP	TX	BNSF	2206.5	*UP*	1733.4
Vermont Yankee NP	VT	BNSF	3331.8	*UP*	3162.5
North Anna NP	VA	BNSF	2940.6	*UP*	2774.3
Surry	VA	BNSF	2937.1	*UP*	2742.0
Hanford	WA	BNSF	1391.2	*UP*	1387.5
WNP 2 NP	WA	BNSF	1415.9	*UP*	1412.1
Kewaunee NP	WI	BNSF	2472.0	*UP*	2292.4
La Crosse NP	WI	*BNSF*	1566.4	UP	1964.4
Point Beach NP	WI	BNSF	2453.1	*UP*	2273.5

a. The railroad used in the routing analysis is denoted in *italic* type.

Table 3-5. Nodes for barge routes[a].

Site	Origin Barge Node	Ending Barge Node	Starting Rail Node[a]
Browns Ferry NP Dock, AL	16812	16587 (Wilson L/D)	8782 (Sheffield)
Diablo Canyon NP Dock, CA	16837	17292 (Port Hueneme)	14701 (Oxnard)
Conn. Yankee NP Dock, CT	16833	16992 (Port of New Haven)	619 (New Haven)
St. Lucie NP Dock, FL	16815	16703 (Port Everglades)	8514 (Fort Lauderdale)
Turkey Point NP Dock, FL	16814	16917 (Port of Miami)	8521 (Miami)
Calvert Cliffs NP Dock, MD	16968	16969 (Port of Baltimore)	2516 (Baltimore)
Pilgrim NP Dock, MA	16834	17254 (Port of Boston)	364 (Boston)
Palisades NP Dock, MI	17268	17269 (Port of Muskegon)	5463 (Muskegon)
Grand Gulf NP Dock, MS	16816	17081 (Port of Vicksburg)	8908 (Vicksburg)
Cooper NP Dock, NE	17144	17145 (Port of Omaha)	11557 (Omaha)
Hope Creek NP Dock, NJ	16979	16972 (Port of Wilmington)	2456 (Wilmington)
Oyster Creek NP Dock, NJ	16828	16991 (Port of Newark)	1245 (Oak Island)
Salem NP Dock, NJ	16980	16972 (Port of Wilmington)	2456 (Wilmington)
Indian Pt. NP Dock, NY	16830	16987 (Port of New Jersey)	1215 (Jersey City)
Surry NP Dock, VA	16959	16956 (Port of Norfolk)	6003 (Norfolk)
Kewaunee NP Dock, WI	16820	17274 (Port of Milwaukee)	5841 (Milwaukee)
Point Beach NP Dock, WI	16821	17274 (Port of Milwaukee)	5841 (Milwaukee)

a. The destination rail nodes for all sites were Apex (node 14763), Beowawe (node 14791), Caliente (node 14770), Crestline (node 16344), Dry Lake (node 16348), Eccles (node 16347), and Jean (node 16328).

Table 3-6. Potentials for Beowawe barge routes.[a]

Site	Intermediate Rail Node	State	Railroad	Potential	Railroad	Potential
Browns Ferry NP Dock, AL	Sheffield	AL	BNSF	2485.1	*UP*	*2310.8*
Diablo Canyon NP Dock, CA	Oxnard	CA	BNSF	1126.4	*UP*	*734.24*
Conn. Yankee NP Dock, CT	New Haven	CT	BNSF	3015.2	*UP*	*2848.9*
St. Lucie NP Dock, FL	Fort Lauderdale	FL	BNSF	3321.7	*UP*	*3118.4*
Turkey Point NP Dock, FL	Miami	FL	BNSF	3355.6	*UP*	*3152.3*
Calvert Cliffs NP Dock, MD	Baltimore	MD	BNSF	2813.5	*UP*	*2647.1*
Pilgrim NP Dock, MA	Boston	MA	BNSF	3004.7	*UP*	*2838.3*
Palisades NP Dock, MI	Muskegon	MI	BNSF	2366.5	*UP*	*2199.9*
Grand Gulf NP Dock, MS	Vicksburg	MS	BNSF	2385.2	*UP*	*2260.9*
Cooper NP Dock, NE	Omaha	NE	BNSF	1135.9	*UP*	*1007.6*
Hope Creek NP Dock, NJ	Wilmington	DE	BNSF	2859.7	*UP*	*2676.9*
Oyster Creek NP Dock, NJ	Oak Island	NJ	BNSF	2912.3	*UP*	*2729.4*
Salem NP Dock, NJ	Wilmington	DE	BNSF	2859.7	*UP*	*2676.9*
Indian Pt. NP Dock, NY	Jersey City	NJ	BNSF	2919.1	*UP*	*2736.2*
Surry NP Dock, VA	Norfolk	VA	BNSF	2975.5	*UP*	*2780.4*
Kewaunee NP Dock, WI	Milwaukee	WI	BNSF	2059.4	*UP*	*1423.0*
Point Beach NP Dock, WI	Milwaukee	WI	BNSF	2059.4	*UP*	*1423.0*

a. The railroad used in the routing analysis is denoted in *italic* type.

3.1.3 ASSUMPTIONS

Throughout the highway routing analysis, it was assumed that SNF and HLW would be shipped as highway-route-controlled quantities and would be subject to U.S. Department of Transportation regulations contained in 49 CFR 397, Subpart D, Routing of Class 7 (Radioactive) Materials. The shipments by rail are still considered highway-route-controlled quantities, but there are no routing regulations for rail. However, other hazardous materials controls for highway-route-controlled quantities (49 CFR Part 171.2(b)) would apply.

3.1.4 USE OF COMPUTER SOFTWARE AND MODELS

Highway and rail routes were analyzed using the routing computer codes HIGHWAY [Version 3.5, Database version HW-1] (DIRS 104780-Johnson et al. 1993, all) and INTERLINE [Version 5.10, Network 15.00] (DIRS 104781-Johnson et al. 1993, all). HIGHWAY and INTERLINE will run on a personal computer using the Windows 95, Windows NT, or Windows 2000 operating systems. HIGHWAY and INTERLINE may also be accessed on TRANSNET (see http://ttd.sandia.gov/risk/transnet.htm).

3.1.5 CALCULATION/ANALYSIS AND RESULTS

Attachment 31A, included on compact disk but not printed due to its length, includes the detailed HIGHWAY and INTERLINE output. The file *Attachment 31A filenames.xls* in Attachment 31A contains a list of files in Attachment 31A, including directory, subdirectory, date, time, size, and filename. Table 3-7 contains a key for the filenames in Attachment 31A.

Table 3-7. Filename key-Attachment 31A. (1 of 2)

Case	Case File Names	Description
1	BELT_1.*	Case 1 HIGHWAY output
2	SPAG_1.*	Case 2 HIGHWAY output
8	CASE_A1.*	Case 8 HIGHWAY output
7	CASE_B1.*	Case 7 HIGHWAY output
4	CASE_C1.*	Case 4 HIGHWAY output
3	CASE_D1.*	Case 3 HIGHWAY output
5	CASE_E1.*	Case 5 HIGHWAY output
6	CASE_F1.*	Case 6 HIGHWAY output

File Names	Description
*.INP	HIGHWAY input file
*.PRN	HIGHWAY output
*.OUT	Map file output
*.SI	Origin name, origin state, destination name, destination state, the distance traveled in the rural, suburban, and urban population zones (km), and the weighted population densities in the rural, suburban, and urban population zones (people/km^2).
*.US	Origin name, origin state, destination name, destination state, the distance traveled in the rural, suburban, and urban population zones (miles), and the weighted population densities in the rural, suburban, and urban population zones (people/mi^2).
*.DNS	Origin name, origin state, destination name, destination state, the population zone (rural, suburban, urban, or total), and the distance traveled in each state (miles) for the population zone. Each origin/destination pair contains 4 rows, one for the state-specific distance traveled in each population zone (rural, suburban, urban, and total).
*.WDS	Origin name, origin state, destination name, destination state, the population zone (rural, suburban, urban, or total), and the weighted population density (people/mi^2) for travel in each state for the population zone. Each origin/destination pair contains 4 rows, one for the state-specific weighted population density for travel in each population zone (rural, suburban, urban, and total).
*.POP	Populations within 800 meters by state and population zone. Populations within 800 meters are calculated using weighted population densities and using assumed population densities. File also contains route miles by state.
*.FIL	HWLKINFO post-processed data.
*.MIF, *.MID	MAKEMAP post-processed data.

Table 3-7. Filename key-Attachment 31A. (2 of 2)

Case	Case File Names	Destinations	Description
Rail	AP_N15.* BE_N15.* CA_N15.* CR_N15.* DL_N15.* EC_N15.* JE_N15.*	Apex Beowawe Caliente Crestline Dry Lake Eccles Jean	Rail INTERLINE output
Rail	BE19_N15.*	Beowawe	INTERLINE output for minimum rail potential
Barge	AP_N15B.* BE_N15B.* CA_N15B.* CR_N15B.* DL_N15B.* EC_N15B.* JE_N15B.*	Apex Beowawe Caliente Crestline Dry Lake Eccles Jean	Barge and rail INTERLINE output
Barge	BE19_BRG.*	Beowawe	INTERLINE output for minimum barge potential

File Names	Description
*.INP	INTERLINE input file
*.PRN	INTERLINE output
*.OUT	Map file output
*.SI	Origin name (including node and railroad), origin state, destination name (including node and railroad), destination state, the distance traveled in the rural, suburban, and urban population zones (km), and the weighted population densities in the rural, suburban, and urban population zones (people/km^2).
*.US	Origin name (including node and railroad), origin state, destination name (including node and railroad), destination state, the distance traveled in the rural, suburban, and urban population zones (miles), and the weighted population densities in the rural, suburban, and urban population zones (people/mi^2).
*.DNS	Origin name (including node and railroad), origin state, destination name (including node and railroad), destination state, the population zone (rural, suburban, urban, or total), and the distance traveled in each state (miles) for the population zone. Each origin/destination pair contains 4 rows, one for the state-specific distance traveled in each population zone (rural, suburban, urban, and total).
*.WDS	Origin name (including node and railroad), origin state, destination name (including node and railroad), destination state, the population zone (rural, suburban, urban, or total), and the weighted population density (people/mi^2) for travel in each state for the population zone. Each origin/destination pair contains 4 rows, one for the state-specific weighted population density for travel in each population zone (rural, suburban, urban, and total).
*.POP	Populations within 800 meters by state and population zone. Populations within 800 meters are calculated using weighted population densities and using assumed population densities. File also contains route miles by state.
*.FIL	RRLKINFO post-processed data.
*.MIF, *.MID	MAKERMAP post-processed data.

3.2 Populations Along National Transportation Routes

3.2.1 INTRODUCTION

This section presents the populations within 800 meters along truck and rail national transportation routes based on the routing cases outlined in Section 3.1. These exposed populations were determined out to 800 meters (2,625 feet) from either side of the routes, using the routes and population densities estimated by the HIGHWAY and INTERLINE routing computer codes. These codes contain population data from the 1990 census. The method used to estimate the exposed populations does not count the exposed population multiple times in areas where routes from several sites converge onto a single route.

3.2.2 METHOD

For truck transportation, the population within 800 meters was estimated for two cases: truck shipments from 81 facilities at 77 sites and truck shipments from 6 sites. The sites included both commercial nuclear facilities and DOE facilities. The 81-site case corresponded to the mostly truck shipping scenario; however, naval SNF shipments from INEEL would be made by rail.

The six-site case corresponded to the mostly rail shipping scenario. For those sites, a truck SNF shipping container was used for a portion of the mostly rail shipping scenario due to facility constraints. The six truck sites were Crystal River, Ginna, Indian Point, Monticello, Pilgrim, and St. Lucie. Because the truck SNF shipping container was used for only a portion of the shipments, under this scenario 71 sites would also ship by rail or barge. The highway routes used Interstate-15; the northern, western, and southern beltway around Las Vegas; and U.S. 95 to Yucca Mountain.

For rail transportation, the populations were estimated for two cases: rail shipments from 77 sites and rail shipments from 1 site. The sites included both commercial nuclear facilities and DOE facilities. The 77-site case corresponded to the mostly rail shipping scenario. The one-site case was for naval SNF shipments from INEEL in the mostly truck shipping scenario.

As in Section 3.1, seven destinations within the State of Nevada were evaluated:

1. Apex (node 14763)
2. Beowawe (node 14791)
3. Caliente (node 14770)
4. Crestline (16344)
5. Dry Lake (node 16348)
6. Eccles (node 16347)
7. Jean (node 16328)

These destinations correspond to the likely locations of potential IMT stations or origins of rail lines that would be built to the Yucca Mountain repository. Populations within 800 meters were estimated for two cases: rail routing to the seven Nevada nodes from those sites with direct rail access and barge and rail routing from 24 sites without direct rail access to the seven Nevada nodes. The barge sites are listed in Table 3-5.

3.2.3 ASSUMPTIONS

Throughout the highway routing analysis, it was assumed that SNF and HLW would be shipped as highway-route-controlled quantities and would be subject to U.S. Department of Transportation regulations contained in 49 CFR 397, Subpart D, Routing of Class 7 (Radioactive) Materials. The shipments by rail are still considered highway-route-controlled quantities, but there are no routing regulations for rail. However, other hazardous materials transportation controls for highway-route-controlled quantities (49 CFR 171.2(b)) would apply.

3.2.4 USE OF COMPUTER SOFTWARE AND MODELS

Highway and rail routes were analyzed using the routing computer codes HIGHWAY [Version 3.5, Database version HW-1] (DIRS 104780-Johnson et al. 1993, all) and INTERLINE [Version 5.10, Network 15.00] (DIRS 104781-Johnson et al. 1993, all). The SUMMARY module of the HIGHWAY and INTERLINE computer codes was used to determine the populations within 800 meters. HIGHWAY and INTERLINE may also be accessed on TRANSNET (see http://ttd.sandia.gov/risk/transnet.htm).

Attachment 31A contains the source code used to estimate populations and population densities within 800 meters of the transportation routes. This program takes the map file output from either the HIGHWAY or INTERLINE model and gathers the population density data for links; it then calculates population counts and distance traveled within each state and within the country. Data for each link are accumulated only once, even though every route may use a particular link.

3.2.5 CALCULATION/ANALYSIS AND RESULTS

Table 3-8 contains the population estimates within 800 meters for the truck transportation case. The population estimates are presented for the states along the routes but do not include the State of Nevada. These population estimates also are presented in Section 3.4.

Tables 3-9 and 3-10 contain the population estimates for the rail and barge transportation cases. The population estimates are presented for the states along the routes but do not include the State of Nevada. These population estimates are presented in Section 3.4.

Attachment 31A, included on compact disk but not printed due to its length, includes the detailed HIGHWAY and INTERLINE output. Table 3-11 provides a key for the population filenames in Attachment 31A. Table 3-12 provides a key for the other filenames in Attachment 31A. The file *Attachment 31A filenames.xls* in Attachment 31A provides a list of files in Attachment 31A, including directory, subdirectory, date, time, size, and filename. Also included in Attachment 31A is the methodology used along with the HIGHWAY and INTERLINE models to estimate populations along the transportation routes.

Table 3-8. Exposed populations for mostly truck shipping scenario. (1 of 2)

	Population within 800 meters							
		Rail End Nodes						
State	Truck Routes	Apex	Beowawe	Caliente	Crestline	Dry Lake	Eccles	Jean
AK	0	0	0	0	0	0	0	0
AL	48,890	0	0	0	0	0	0	0
AR	9,221	0	0	0	0	0	0	0
AZ	118,601	0	0	0	0	0	0	0
CA	965,534	0	0	0	0	0	0	0
CO	32,033	0	0	0	0	0	0	0
CT	305,946	0	0	0	0	0	0	0
DE	20,514	0	0	0	0	0	0	0
FL	492,561	0	0	0	0	0	0	0
GA	303,332	0	0	0	0	0	0	0
HI	0	0	0	0	0	0	0	0
IA	63,268	0	0	0	0	0	0	0
ID	52,336	19,919	19,919	19,919	19,919	19,919	19,919	19,919
IL	250,592	0	0	0	0	0	0	0
IN	92,796	0	0	0	0	0	0	0
KS	40,350	0	0	0	0	0	0	0
KY	85,743	0	0	0	0	0	0	0
LA	171,559	0	0	0	0	0	0	0
MA	226,808	0	0	0	0	0	0	0
MD	259,146	0	0	0	0	0	0	0
ME	34,125	0	0	0	0	0	0	0
MI	170,035	0	0	0	0	0	0	0
MN	123,165	0	0	0	0	0	0	0
MO	144,296	0	0	0	0	0	0	0
MS	16,270	0	0	0	0	0	0	0
MT	0	0	0	0	0	0	0	0
NC	237,152	0	0	0	0	0	0	0
ND	0	0	0	0	0	0	0	0
NE	51,069	0	0	0	0	0	0	0
NH	9,496	0	0	0	0	0	0	0
NJ	106,210	0	0	0	0	0	0	0
NM	83,391	0	0	0	0	0	0	0
NV	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)
NY	367,232	0	0	0	0	0	0	0
OH	237,880	0	0	0	0	0	0	0
OK	79,937	0	0	0	0	0	0	0
OR	47,436	0	0	0	0	0	0	0
PA	371,792	0	0	0	0	0	0	0
RI	0	0	0	0	0	0	0	0
SC	88,920	0	0	0	0	0	0	0
SD	0	0	0	0	0	0	0	0
TN	158,131	0	0	0	0	0	0	0
TX	371,862	0	0	0	0	0	0	0
UT	225,121	74,830	6,205	74,830	74,830	74,830	74,830	74,830
VA	99,531	0	0	0	0	0	0	0

Table 3-8. Exposed populations for mostly truck shipping scenario. (2 of 2)

	Population within 800 meters							
		Rail End Nodes						
State	Truck Routes	Apex	Beowawe	Caliente	Crestline	Dry Lake	Eccles	Jean
VT	9,298	0	0	0	0	0	0	0
WA	45,243	0	0	0	0	0	0	0
WI	159,600	0	0	0	0	0	0	0
WV	101,009	0	0	0	0	0	0	0
WY	28,218	0	0	0	0	0	0	0
DC	0	0	0	0	0	0	0	0
Total	6,905,649	94,749	26,124	94,749	94,749	94,749	94,749	94,749

a. The exposed population for Nevada is presented in Section 3.4.

Table 3-9. Exposed populations for mostly rail shipping scenario. (1 of 2)

	Population within 800 meters							
		Rail End Nodes						
State	Truck Routes	Apex	Beowawe	Caliente	Crestline	Dry Lake	Eccles	Jean
AK	0	0	0	0	0	0	0	0
AL	0	9,981	9,981	9,981	9,981	9,981	9,981	46,403
AR	0	20,734	20,734	20,734	20,734	20,734	20,734	11,651
AZ	77	44,396	4,164	44,396	4,164	44,396	44,396	73,447
CA	0	1,399,184	1,493,078	1,323,483	1,323,483	1,399,184	1,323,483	1,401,306
CO	0	104,169	187,131	200,350	200,350	200,350	200,350	104,169
CT	0	157,627	157,627	157,627	157,627	157,627	157,627	157,627
DE	0	0	0	0	0	0	0	0
FL	114,117	614,192	614,192	614,192	614,192	614,192	614,192	710,224
GA	141,082	477,767	477,767	477,767	477,767	477,767	477,767	403,639
HI	0	0	0	0	0	0	0	0
IA	34,048	244,430	244,430	244,430	244,430	244,430	244,430	183,742
ID	43,822	50,259	50,259	50,259	50,259	50,259	50,259	50,259
IL	101,160	1,135,539	1,135,539	1,135,539	1,135,539	1,135,539	1,135,539	1,134,188
IN	69,538	417,153	417,153	417,153	417,153	417,153	417,153	417,153
KS	0	70,757	70,757	70,757	70,757	70,757	70,757	102,225
KY	11,745	86,551	86,551	86,551	86,551	86,551	86,551	86,551
LA	0	125,216	162,280	162,969	162,969	125,216	162,969	226,195
MA	87,055	421,745	421,745	421,745	421,745	421,745	421,745	421,745
MD	0	150,798	150,798	150,798	150,798	150,798	150,798	150,798
ME	0	38,740	38,740	38,740	38,740	38,740	38,740	38,740
MI	0	364,834	364,834	364,834	364,834	364,834	364,834	364,834
MN	69,285	196,692	196,692	196,692	196,692	196,692	196,692	196,692
MO	143,920	356,817	356,817	356,817	356,817	356,817	356,817	308,001
MS	0	357	357	357	357	357	357	61,370
MT	0	0	0	0	0	0	0	0
NC	0	191,551	191,551	191,551	191,551	191,551	191,551	191,551
ND	0	0	0	0	0	0	0	0
NE	49,961	214,213	214,213	214,213	214,213	214,213	214,213	210,989
NH	0	27,005	27,005	27,005	27,005	27,005	27,005	27,005
NJ	54,086	391,159	391,159	391,159	391,159	391,159	391,159	391,159
NM	0	8,281	226	8,281	0	8,281	8,281	24,068
NV	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)
NY	236,874	504,338	504,338	504,338	504,338	504,338	504,338	504,338
OH	215,674	1,080,750	1,080,750	1,080,750	1,080,750	1,080,750	1,080,750	1,080,750

Table 3-9. Exposed populations for mostly rail shipping scenario. (2 of 2)

	Population within 800 meters							
	Truck	Rail End Nodes						
State	Routes	Apex	Beowawe	Caliente	Crestline	Dry Lake	Eccles	Jean
OK	0	24,457	24,576	24,576	24,576	24,576	24,576	14,069
OR	11,585	266,869	266,869	156,010	156,010	266,869	156,010	266,869
PA	50,488	955,677	955,677	955,677	955,677	955,677	955,677	955,677
RI	0	0	0	0	0	0	0	0
SC	0	212,998	212,998	212,998	212,998	212,998	212,998	212,998
SD	0	394	394	394	394	394	394	394
TN	62,203	192,018	192,018	192,018	192,018	192,018	192,018	192,018
TX	0	428,619	393,130	564,345	557,402	399,991	646,263	608,624
UT	225,121	106,880	135,415	106,880	106,880	106,880	106,880	106,880
VA	0	168,560	168,560	168,560	168,560	168,560	168,560	168,560
VT	0	1,831	1,831	1,831	1,831	1,831	1,831	1,831
WA	21,379	30,337	30,337	30,337	30,337	30,337	30,337	30,337
WI	0	153,990	153,990	153,990	153,990	153,990	153,990	153,990
WV	0	59,951	59,951	59,951	59,951	59,951	59,951	59,951
WY	28,123	19,457	19,478	19,457	19,457	19,457	19,457	19,457
DC	0	72,104	72,104	72,104	72,104	72,104	72,104	72,104
Total	**1,771,343**	**11,599,377**	**11,758,196**	**11,682,596**	**11,627,140**	**11,667,049**	**11,764,514**	**11,944,578**

a. The exposed population for Nevada is presented in Section 3.4.

Table 3-10. Exposed populations for mostly rail shipping scenario with barge. (1 of 2)

	Population within 800 meters							
		Rail End Nodes						
State	Truck Routes	Apex	Beowawe	Caliente	Crestline	Dry Lake	Eccles	Jean
AK	0	0	0	0	0	0	0	0
AL	0	10,138	10,138	10,138	10,138	10,138	10,138	46,559
AR	0	20,734	20,734	20,734	20,734	20,734	20,734	11,651
AZ	77	44,396	4,164	44,396	4,164	44,396	44,396	73,447
CA	0	1,331,075	1,575,710	1,255,373	1,255,373	1,331,075	1,255,373	1,333,196
CO	0	104,169	187,131	200,350	200,350	200,350	200,350	104,169
CT	0	142,767	142,767	142,767	142,767	142,767	142,767	142,767
DE	0	23,003	23,003	23,003	23,003	23,003	23,003	23,003
FL	114,117	390,366	390,366	390,366	390,366	390,366	390,366	484,712
GA	141,082	477,767	477,767	477,767	477,767	477,767	477,767	403,639
HI	0	0	0	0	0	0	0	0
IA	34,048	244,430	244,430	244,430	244,430	244,430	244,430	183,742
ID	43,822	50,259	50,259	50,259	50,259	50,259	50,259	50,259
IL	101,160	1,095,939	1,095,939	1,095,939	1,095,939	1,095,939	1,095,939	1,094,586
IN	69,538	417,152	417,152	417,152	417,152	417,152	417,152	417,152
KS	0	70,757	70,757	70,757	70,757	70,757	70,757	102,225
KY	11,745	88,707	88,707	88,707	88,707	88,707	88,707	88,707
LA	0	125,216	162,280	162,969	162,969	125,216	162,969	226,195
MA	87,055	399,529	399,529	399,529	399,529	399,529	399,529	399,529
MD	0	162,228	162,228	162,228	162,228	162,228	162,228	162,228
ME	0	38,740	38,740	38,740	38,740	38,740	38,740	38,740
MI	0	394,318	394,318	394,318	394,318	394,318	394,318	394,318
MN	69,285	196,692	196,692	196,692	196,692	196,692	196,692	196,692
MO	143,920	356,817	356,817	356,817	356,817	356,817	356,817	308,001
MS	0	4,761	4,761	4,761	4,761	4,761	4,761	65,779
MT	0	0	0	0	0	0	0	0
NC	0	191,551	191,551	191,551	191,551	191,551	191,551	191,551

Table 3-10. Exposed populations for mostly rail shipping scenario with barge. (2 of 2)

State	Truck Routes	Population within 800 meters						
		Rail End Nodes						
		Apex	Beowawe	Caliente	Crestline	Dry Lake	Eccles	Jean
ND	0	0	0	0	0	0	0	0
NE	49,961	185,521	185,521	185,521	185,521	185,521	185,521	182,297
NH	0	27,005	27,005	27,005	27,005	27,005	27,005	27,005
NJ	54,086	186,805	186,805	186,805	186,805	186,805	186,805	186,805
NM	0	8,281	226	8,281	0	8,281	8,281	24,068
NV	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)
NY	236,874	446,190	446,190	446,190	446,190	446,190	446,190	446,190
OH	215,674	1,080,750	1,080,750	1,080,750	1,080,750	1,080,750	1,080,750	1,080,750
OK	0	24,457	24,576	24,576	24,576	24,576	24,576	14,069
OR	11,585	266,869	266,869	156,010	156,010	266,869	156,010	266,869
PA	50,488	831,354	831,354	831,354	831,354	831,354	831,354	831,354
RI	0	0	0	0	0	0	0	0
SC	0	212,998	212,998	212,998	212,998	212,998	212,998	212,998
SD	0	394	394	394	394	394	394	394
TN	62,203	202,865	202,865	202,865	202,865	202,865	202,865	202,865
TX	0	428,619	393,130	564,345	557,402	399,991	646,263	608,624
UT	225,121	106,880	135,415	106,880	106,880	106,880	106,880	106,880
VA	0	189,164	189,164	189,164	189,164	189,164	189,164	189,164
VT	0	1,831	1,831	1,831	1,831	1,831	1,831	1,831
WA	21,379	30,337	30,337	30,337	30,337	30,337	30,337	30,337
WI	0	55,478	55,478	55,478	55,478	55,478	55,478	55,478
WV	0	59,951	59,951	59,951	59,951	59,951	59,951	59,951
WY	28,123	19,457	19,478	19,457	19,457	19,457	19,457	19,457
DC	0	26,204	26,204	26,204	26,204	26,204	26,204	26,204
W[b]	0	502,132	502,132	502,132	502,132	502,132	502,132	502,132
Total	1,771,343	11,275,053	11,584,613	11,358,271	11,302,815	11,342,725	11,440,189	11,618,569

a. The exposed population for Nevada is presented in Section 3.4.
b. W denotes the exposed population along waterways.

Table 3-11. Population filename key-Attachment 31A.

Case	Mode	Number of Sites	Filename
Mostly Truck	Truck	81	BELT_1.POP
	Rail	1 (Apex)	AP_USN.POP
	Rail	1 (Beowawe)	BE_USN.POP
	Rail	1 (Caliente)	CA_USN.POP
	Rail	1 (Crestline)	CR_USN.POP
	Rail	1 (Dry Lake)	DL_USN.POP
	Rail	1 (Eccles)	EC_USN.POP
	Rail	1 (Jean)	JE_USN.POP
Mostly Rail	Truck	8	BELT_081.POP
	Rail	80 (Apex)	AP_N15.POP
	Rail	80 (Beowawe)	BE_N15.POP
	Rail	80 (Caliente)	CA_N15.POP
	Rail	80 (Crestline)	CR_N15.POP
	Rail	80 (Dry Lake)	DL_N15.POP
	Rail	80 (Eccles)	EC_N15.POP
	Rail	80 (Jean)	JE_N15.POP
	Truck	8	BELT_081.POP

Table 3-11. Population filename key-Attachment 31A.

Case	Mode	Number of Sites	Filename
	Rail and Barge	80 (Apex)[a]	AP_N15B.POP
	Rail and Barge	80 (Beowawe)[a]	BE_N15B.POP
	Rail and Barge	80 (Caliente)[a]	CA_N15B.POP
	Rail and Barge	80 (Crestline)[a]	CR_N15B.POP
	Rail and Barge	80 (Dry Lake)[a]	DL_N15B.POP
	Rail and Barge	80 (Eccles)[a]	EC_N15B.POP
	Rail and Barge	80 (Jean)[a]	JE_N15B.POP

a. 17 barge sites and 63 rail sites.

Table 3-12. Filename key-Attachment 31A (other filenames). (1 of 2)

Case	Case File Names	Description
81 truck sites	BELT_1.*	81 site HIGHWAY output
8 truck sites	BELT_081.*	8 site HIGHWAY output
Case File Names	Description	
*.INP	HIGHWAY input file	
*.PRN	HIGHWAY output	
*.OUT	Map file output	
*.SI	Origin name, origin state, destination name, destination state, the distance traveled in the rural, suburban, and urban population zones (km), and the weighted population densities in the rural, suburban, and urban population zones (people/km^2).	
*.US	Origin name, origin state, destination name, destination state, the distance traveled in the rural, suburban, and urban population zones (miles), and the weighted population densities in the rural, suburban, and urban population zones (people/mi^2).	
*.DNS	Origin name, origin state, destination name, destination state, the population zone (rural, suburban, urban, or total), and the distance traveled in each state (miles) for the population zone. Each origin/destination pair contains 4 rows, one for the state-specific distance traveled in each population zone (rural, suburban, urban, and total).	
*.WDS	Origin name, origin state, destination name, destination state, the population zone (rural, suburban, urban, or total), and the weighted population density (people/mi^2) for travel in each state for the population zone. Each origin/destination pair contains 4 rows, one for the state-specific weighted population density for travel in each population zone (rural, suburban, urban, and total).	
*.POP	Exposed population by state and population zone. Exposed populations are calculated using weighted population densities. File also contains route miles by state.	
*.FIL	HWLKINFO post-processed data.	
*.MIF, *.MID	MAKEMAP post-processed data.	

Table 3-12. Filename key-Attachment 31A (other filenames. (2 of 2)

Case	Case File Names	Destinations	Description
Rail	AP_N15.*	Apex	Rail INTERLINE output
	BE_N15.*	Beowawe	(80 sites)
	CA_N15.*	Caliente	
	CR_N15.*	Crestline	
	DL_N15.*	Dry Lake	
	EC_N15.*	Eccles	
	JE_N15.*	Jean	
Rail	AP_USN.*	Apex	Rail INTERLINE output
	BE_USN.*	Beowawe	(1 site)
	CA_USN.*	Caliente	
	CR_USN.*	Crestline	
	DL_USN.*	Dry Lake	
	EC_USN.*	Eccles	
	JE_USN.*	Jean	
Rail and Barge	AP_N15B.*	Apex	Barge and rail INTERLINE output
	BE_N15B.*	Beowawe	(17 barge sites and 63 rail sites)
	CA_N15B.*	Caliente	
	CR_N15B.*	Crestline	
	DL_N15B.*	Dry Lake	
	EC_N15B.*	Eccles	
	JE_N15B.*	Jean	
File Names	Description		
*.INP	INTERLINE input file		
*.PRN	INTERLINE output		
*.OUT	Map file output		
*.SI	Origin name (including node and railroad), origin state, destination name (including node and railroad), destination state, the distance traveled in the rural, suburban, and urban population zones (km), and the weighted population densities in the rural, suburban, and urban population zones (people/km^2).		
*.US	Origin name (including node and railroad), origin state, destination name (including node and railroad), destination state, the distance traveled in the rural, suburban, and urban population zones (miles), and the weighted population densities in the rural, suburban, and urban population zones (people/mi^2).		
*.DNS	Origin name (including node and railroad), origin state, destination name (including node and railroad), destination state, the population zone (rural, suburban, urban, or total), and the distance traveled in each state (miles) for the population zone. Each origin/destination pair contains 4 rows, one for the state-specific distance traveled in each population zone (rural, suburban, urban, and total).		
*.WDS	Origin name (including node and railroad), origin state, destination name (including node and railroad), destination state, the population zone (rural, suburban, urban, or total), and the weighted population density (people/mi^2) for travel in each state for the population zone. Each origin/destination pair contains 4 rows, one for the state-specific weighted population density for travel in each population zone (rural, suburban, urban, and total).		
*.POP	Exposed population by state and population zone. Exposed populations are calculated using weighted population densities. File also contains route miles by state.		
*.FIL	RRLKINFO post-processed data.		
*.MIF, *.MID	MAKERMAP post-processed data.		

3.3 Routing - Nevada

3.3.1 INTRODUCTION

This section presents the development of the distance and population density data (in kilometers and persons per square kilometer) for routes in Nevada using the Geographic Information Software Arc View/Arc Info. The data, which includes distances and population densities through each county for each route, were developed for the Nevada routing alternatives analyzed in the Yucca Mountain FEIS. The data were provided by mile for each route. Attachment 3.3a presents the output data from the Arc View/Arc Info code for each route analyzed in Nevada, including the legal-weight truck sensitivity cases. In addition to estimating transportation impacts in Nevada, those data were used to estimate the population counts within 1.6 kilometers (1 mile) of the transportation route (the region of influence for radiological transportation impacts) and within 2 kilometers (1.2 miles) of the route for the noise impact region of influence (see Section 3.3.5). The routing in Nevada also considered routing options or variations for some of the routes analyzed. The variation in route characteristics (length or population density) was not significant enough to warrant individual evaluation. The routes analyzed were selected to be representative of all of the variations for a particular route.

3.3.2 METHOD

Attachment 33A contains the routing and population data, including maps generated using Arc View/Arc Info. The analysis was performed utilizing GIS (Geographical Information System) technology and two primary sources of data: population data and route data. The 2000 Census Redistricting GIS Block Level data were downloaded by individual Nevada counties, and a statewide dataset was created from these downloads. In addition, the population count database was also downloaded and joined to the GIS data. The field P0010001 (see U.S. Census Redistricting Technical Information) was used for total population count per block. A field called pop_dens (in persons per km^2) was calculated based on total population and area of the block. The routes themselves came from various sources. The potential rail routes were received from Morrison-Knudsen in 1998. The Heavy-Haul, Legal-Weight Truck and Sensitivity routes were created using USGS 1:24,000 scale Digital Line Graph (DLG) files. The Commercial Rail routes were created from a combination of 1:24,000 USGS DLGs and screen digitizing of alignments based on 1:100,000 USGS Digital Raster Graphs (DRG) (screen digitizing occurred only where the data were not available on the 1:24,000 scale DLGs). The routine selected each route, which was then segmented into mile-long sections. Each mile-long section was buffered 800 meters (2,600 feet) on each side of the alignment, and the resultant coverage was used to clip out the block and population data for that segment. Total population counts for each section were derived using the pop_dens field and the area of each block that was covered by the buffered area. The cumulative statistics were summarized by county for each mile-long segment and appended to an output comma-separated value (.csv) file. It is these cumulative files that can be found in the attached archive. There were approximately 9,500 total kilometers (5,900 total miles) of alternatives analyzed. The population counts for the State of Nevada only have been reported. The attachment, which is provided electronically on a compact disk, contains all of the supporting data for the transportation analyses.

3.3.2.1 Legal-Weight Truck Routes in Nevada

The legal-weight truck routing in Nevada would follow Interstate System Highways (I-15) unless the State of Nevada designated alternative or additional preferred routes as prescribed under regulations of the U.S. Department of Transportation (49 CFR 397.103). Legal-weight trucks would follow Interstate-15 in Nevada from the north or south to the Las Vegas beltway and U.S. 95 to Yucca Mountain. To illustrate how the data presented in Attachment 33A were used, Figure 3-1 presents two legal-weight truck routes: one using the Las Vegas beltway and the second using the "spaghetti bowl" (Interstate-15 through downtown Las Vegas). Table 3-13 presents the link numbers that correspond with routing designations in Figure 3-1. Additional figures that provide routing for each of the Nevada implementing alternatives and for existing rail lines in Nevada can be found in Attachment 33A.

Attachment 33A provides the routing data for each county by mile, including the population density for each mile segment. The data were combined to determine the distance and population density in each county by population zone. The combination of links presented in Table 3-13 for each route provides the total distance. Link segments are typically identified to begin or end at logical break points where the route changes county or the highway designation changes. The population counts for a given route were organized by county and by population zone (rural, suburban, and urban) to determine population density by population zone.

Also provided in Attachment 33A are the routing data for the Nevada legal-weight truck sensitivity routes. Seven routes were analyzed that included the use of Interstate-15 and the Las Vegas "spaghetti bowl" and six routes identified in a 1998 study by the Nevada Department of Transportation (DIRS 103072-Ardila-Coulson 1989, pp. 36 and 45). These routes were analyzed to present the results of the sensitivity of transportation impacts to variations of legal-weight truck routing in Nevada. Table 3-14 describes each of the sensitivity cases for legal-weight truck routing.

3.3.2.2 Rail Implementing Alternatives in Nevada

The routes and lengths for heavy-haul truck and rail implementing alternatives in Nevada were obtained from the Nevada Transportation Engineering File (DIRS 155347-CRWMS M&O 1999, all). The routing analyzed in the FEIS was for five branch rail line routes and five heavy-haul routes. The routing information was used in combination with Geographic Information System (GIS) data for the State of Nevada, including census blocks along the route used to estimate population density and distances for each route. The routing data (population along segments) provided through Arc View/Arc Info divided the routes up into 1.6-kilometer (1-mile) long segments and organized the segments by links, which were associated with a particular route or piece of route through a specific county. Each link includes the population density in persons per square kilometer for each 1.6-kilometer (1-mile) long segment. The data were combined to determine the distance and population density in each county by population zone. Attachment 33A provides the rail and heavy-haul route data obtained by using Arc View/Arc Info.

3.3.2.3 Commercial Rail Lines in Nevada

Section 3.1 presented the national routing for shipments to Nevada for the Yucca Mountain FEIS. For rail transportation, six end nodes in Nevada were presented. From one of those six end nodes, each of the routing alternatives in Nevada begins. Routing on existing rail lines in Nevada to these ends nodes was evaluated using GIS data, and the population densities along these commercial rail routes by county were identified. These data, along with the routing data from rail implementing alternatives above, were used to estimate transportation impacts in Nevada. Attachment 33A provides the rail and heavy-haul route population data obtained by using Arc View/Arc Info.

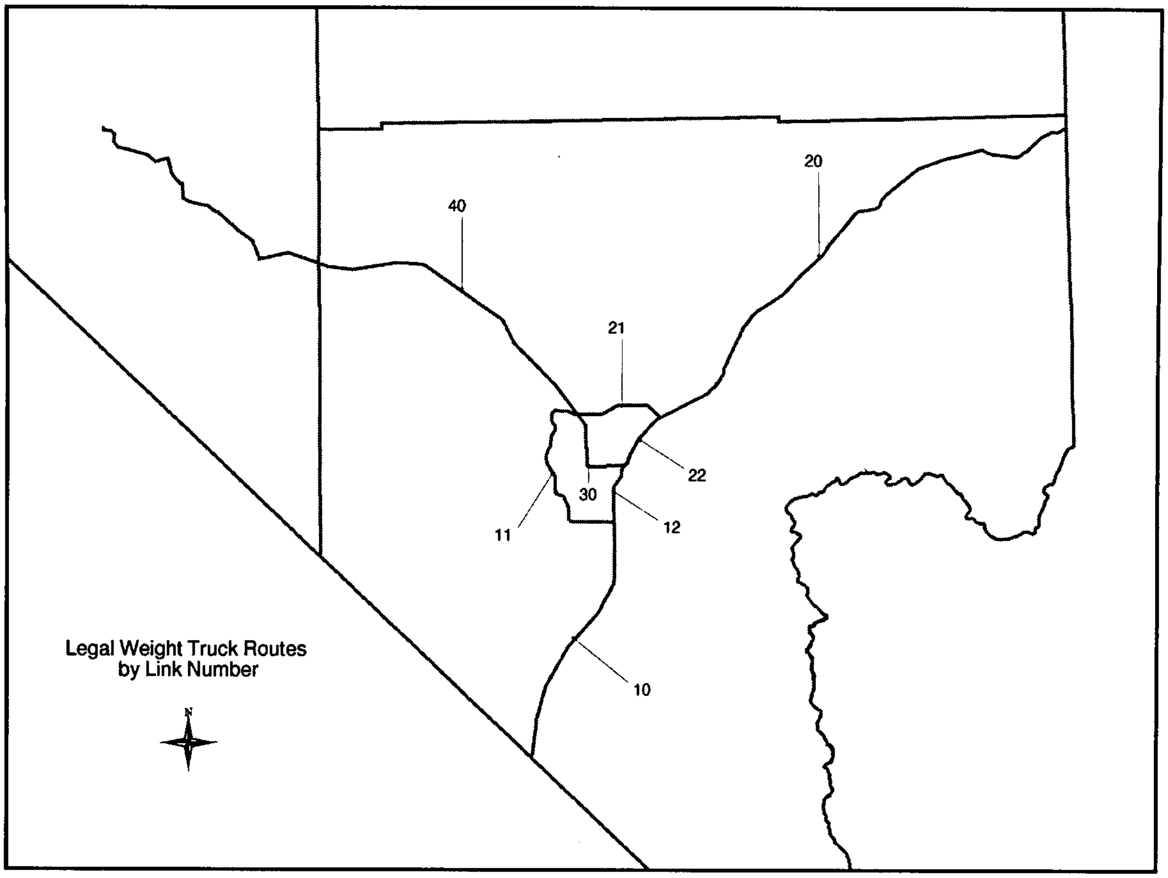

Figure 3-1. Legal-weight truck routing in Nevada for the Las Vegas beltway and the "spaghetti bowl" (Source Attachment 33A).

Table 3-13. Legal-weight truck routes by link number.

Legal-Weight Truck Routes by Link Number			
Spaghetti Bowl South	**Spaghetti Bowl North**	**Beltway South**	**Beltway North**
40	20	40	20
30	22	11	21
12	30	10	40
10	40		

Table 3-14. Legal-weight truck sensitivity cases.

Case	Description
1	To Yucca Mountain via Barstow, California, using I-15 to Nevada 160 to Nevada 160 (Nevada D and F)
2	To Yucca Mountain via Barstow using I-15 to California Route 127 to Nevada 373 to US 95 (Nevada C)
3	To Yucca Mountain via Needles using U.S. 95 to Nevada 164 to I-15 to California 127 to Nevada 373 and U.S. 95 (Nevada E)
4	To Yucca Mountain via Needles using U.S. 95 to Nevada 164 to I-15 to Nevada 160 (variation of Nevada E)
5	To Yucca Mountain via Wendover using U.S. 93 Alternate to U.S. 93 to US 6 to U.S. 95 (Nevada B) (E00290C)
6	To Yucca Mountain via Wendover using U.S. 93 Alternate to U.S. 93 to Nevada 318 to U.S. 93 to I-15 to the Las Vegas Beltway to U.S. 95 (Nevada A)
7	To Yucca Mountain via Las Vegas using I-15 (for shipments entering Nevada at both the Arizona and California borders) to U.S. 95 ("spaghetti bowl" interchange)

3.3.3 ASSUMPTIONS

The routing in Nevada used the following assumptions:

- The region of influence for radiological health and safety impacts is 30 meters (98 feet) to 800 meters (2,625 feet) on each side of the route (1.6 kilometers [1 mile]). This distance was used for estimating population density and population counts along each route for use in the health and safety analysis.

- Highway routes for legal-weight truck were determined using the HIGHWAY model as discussed in Section 3.1.

- Commercial rail routes in Nevada were determined using the INTERLINE model as discussed in Section 3.1.

- Heavy-haul routes and rail corridor routing in Nevada was provided in the Nevada Transportation Engineering File (DIRS 155347-CRWMS M&O 1999, all).

- Populations along the route in Nevada were determined using GIS data (See Attachment33A).

- The estimate of the population along the Las Vegas beltway was taken from DIRS 155112-Berger 2000, pp. 1 to 2.

- The populations along the route were escalated to the year 2035 as discussed in Section 3.4.

- The region of influence for noise impacts is 2 kilometers (1.2 miles) on each side of the route (4 kilometers [2.4 miles]). This distance was used for estimating population counts for each route for use in the noise analysis.

3.3.4 USE OF COMPUTER SOFTWARE/MODELS

Population density and distances for routing in Nevada were estimated using the ARC View/ARC Info system (DIRS 155931-Knop 2001, all). These calculations were performed on a personal computer using the Windows 2000 operating system and Microsoft® Excel 2000 spreadsheets.

3.3.5 CALCULATION/ANALYSIS AND RESULTS

Table 3-15 presents the distances and population densities for the legal-weight truck routing using the Las Vegas beltway (base case) and legal-weight truck sensitivity cases. Table 3-16 presents the population counts for the legal-weight truck route using the Las Vegas beltway (base case).

The rail and heavy-haul truck implementing alternatives for transportation in Nevada include five possible rail corridors and five possible heavy-haul truck routes. Table 3-17 presents the distances and population densities by county for each of the implementing alternatives. The distances reported in Table 3-17 for the branch rail lines are entirely through rural population areas. However, three of the heavy-haul routes have both rural and suburban kilometers. For the heavy-haul truck, the suburban distance traveled in Nevada consists of travel along the Las Vegas beltway (northern, southern, and western). For these distances, the population density was estimated to be approximately 1,592 persons per square kilometer based on projections for the year 2020 (DIRS 155112-Berger 2000, pp.1 and 2). Table 3-18 presents the population counts for the rail and heavy-haul truck implementing alternatives.

Table 3-19 presents the distances and population densities by county for the existing rail lines in Nevada that are used in the transportation analysis.

Table 3-20 presents the population counts within 1.6 kilometers (1 mile) of the rail line for existing rail routes in Nevada.

The 2035 population estimates in Tables 3-16, 3-18, and 3-20 present population estimates for the year 2035. The data and the methodology for the escalation of the population from 1990 to 2035 are presented in Section 3.4.

Attachment 33A, included on compact disk but not printed due to its length, includes the detailed Arc View/Arc Info output data with maps for each transportation mode. Table 3-21 provides a key for the filenames in Attachment 33A. The *Attachment 33A filenames.xls* file in Attachment 33A provides a list of files in Attachment 33A, including directory, subdirectory, date, time, size, and filename.

Table 3-15. Distances and population density by county for legal-weight truck routes in Nevada.

Route	County	Distance (km) Urban	Suburban	Rural	Total	Population Density (persons/km^2) Urban	Suburban	Rural
Legal-Weight Truck Routes in Nevada - Beltway - Base Case								
Route from the North	Clark	0.0	19.9	187.5	**207.4**	0.0	1592.3[a]	10.6
Route from the North	Nye	0.0	0.0	64.7	**64.7**	0.0	0.0	0.0
Route from the South	Clark	0.0	41.9	126.9	**168.8**	0.0	1592.3[a]	3.5
Route from the South	Nye	0.0	0.0	64.7	**64.7**	0.0	0.0	0.0
Legal-Weight Truck Routes in Nevada - Spaghetti Bowl								
Route from the North	Clark	3.2	19.3	183.5	**206.0**	1,780.5	904.7	1.8
Route from the North	Nye	0.0	0.0	64.4	**64.4**	0.0	0.0	0.0
Route from the South	Clark	11.3	22.9	125.9	**160.0**	2,163.4	621.7	4.9
Route from the South	Nye	0.0	0.0	64.7	**64.7**	0.0	0.0	0.0
Legal-Weight Truck Routes in Nevada - Sensitivity A								
Route from the North	Elko	0.0	0.0	86.1	**86.1**	0.0	0.0	1.3
Route from the North	White Pine	0.0	8.7	173.8	**182.5**	0.0	427.3	1.9
Route from the South	Lincoln	0.0	0.0	172.7	**172.7**	0.0	0.0	0.1
Route from the South	Clark	0.0	12.9	156.9	**169.8**	0.0	368.0	2.3
Route from the South	Nye	0.0	0.0	113.5	**113.5**	0.0	0.0	0.0
		0.0	21.6	703.0	**724.5**			
Legal-Weight Truck Routes in Nevada - Sensitivity B								
Route from the North	Elko	0.0	0.0	85.3	**85.3**	0.0	0.0	1.3
Route from the North	White Pine	0.0	8.7	159.3	**168.0**	0.0	427.3	1.8
Route from the North	Esmeralda	0.0	0.0	71.6	**71.6**	0.0	0.0	1.8
Route from the North	Nye	0.0	3.7	358.9	**362.6**	0.0	322.6	0.7
		0.0	12.4	675.1	**687.5**			
Legal-Weight Truck Routes in Nevada - Sensitivity C								
Route from the South	Nye	0.0	0.0	52.6	**52.6**	0.0	0.0	2.1
		0.0	0.0	52.6	**52.6**			
Legal-Weight Truck Routes in Nevada - Sensitivity D								
Route from the South	Clark	0.0	3.2	127.1	**130.4**	0.0	76.0	4.1
Route from the South	Nye	0.0	0.0	105.4	**105.4**	0.0	0.0	3.6
		0.0	3.2	232.6	**235.8**			
Legal-Weight Truck Routes in Nevada - Sensitivity E								
Route from the South	Clark	0.0	1.6	66.0	**67.6**	0.0	127.9	1.8
Route from the South	Nye	0.0	0.0	52.6	**52.6**	0.0	0.0	2.1
		0.0	1.6	118.6	**120.2**			
Legal-Weight Truck Routes in Nevada - Sensitivity F								
Route from the South	Clark	0.0	3.2	127.1	**130.4**	0.0	76.0	4.1
Route from the South	Nye	0.0	0.0	105.4	**105.4**	0.0	0.0	3.6
		0.0	3.2	232.6	**235.8**			
Legal-Weight Truck Routes in Nevada - Sensitivity Northern Route								
Route across the North	Elko	0.0	11.3	202.5	**213.7**	0.0	458.7	4.1
Route across the North	Eureka	0.0	0.0	41.7	**41.7**	0.0	0.0	0.1
Route across the North	Humboldt	0.0	6.4	93.3	**99.8**	0.0	250.8	3.6
Route across the North	Lander	0.0	3.2	39.4	**42.6**	0.0	641.7	4.7
Route across the North	Lyon	0.0	3.2	11.0	**14.2**	0.0	171.2	2.2
Route across the North	Pershing	0.0	3.2	117.5	**120.7**	0.0	394.2	2.9
Route across the North	Storey	0.0	1.6	18.8	**20.4**	0.0	226.9	5.5
Route across the North	Washoe	6.4	16.9	32.7	**56.0**	2,071.7	518.0	12.7
Route across the North	Churchill	0.0	0.0	51.9	**51.9**	0.0	0.0	0.0

a. DIRS 155112-Berger 2000, p. 1 and 2 – This is a projected population along the Las Vegas beltway for the year 2020

Table 3-16. Population counts by county for the base case legal-weight truck route in Nevada.

Route	County	Population Counts (1990 Census Data) Urban	Suburban	Rural	Total	Escalated to the year 2035 Total	Total (2035)
Legal-Weight Truck Routes in Nevada - Beltway - Base Case							
Route from the North	Clark	0.00	50,697	3,180	53,877	196,113	
Route from the North	Nye	0.00	0.00	0.06	0.06	0	196,113
Route from the South	Clark	0.00	106,745	717	107,462	391,161	
Route from the South	Nye	0.00	0.00	0.06	0.06	0	391,162

Table 3-17. Distances and population densities by county for rail and heavy-haul truck implementing alternatives.

End Node	Origin	Implementing Alternative	County	Kilometers Urban	Suburban	Rural	Total	Population Density (persons/km^2) Urban	Suburban	Rural
Branch Rail Lines										
Yucca Mountain	Eccles	Caliente/Chalk Mountain	Lincoln	0	0	158	158	0	0	0.0
		Caliente/Chalk Mountain	Nye	0	0	188.0	188.0	0	0	0.0
		Caliente	Esmeralda	0	0	4.0	4.0	0	0	0.3
		Caliente	Lincoln	0	0	148.5	148.5	0	0	0.0
		Caliente	Nye	0	0	360.8	360.8	0	0	0.1
	Beowawe	Carlin	Esmeralda	0	0	41.0	41.0	0	0	0.4
		Carlin	Eureka	0	0	29.8	29.8	0	0	0.1
		Carlin	Lander	0	0	158.7	158.7	0	0	0.0
		Carlin	Nye	0	0	291.5	291.5	0	0	0.6
	Jean	Jean	Clark	0	0	82.4	82.4	0	0	0.8
		Jean	Nye	0	0	98.2	98.2	0	0	0.2
	Valley Modified	Apex	Clark	0	0	99.5	99.5	0	0	0.1
		Apex	Nye	0	0	59.2	59.2	0	0	0.0
Heavy-Haul Routes										
Yucca Mountain	Dry Lake	Apex/Dry Lake	Clark	0	19.9	104.0	123.9	0	1,592.3[a]	2.9
		Apex/Dry Lake	Nye	0	0	59.4	59.4	0	0.0	0.0
	Caliente	Caliente	Esmeralda	0	0	71.6	71.6	0	0.0	2.0
		Caliente	Lincoln	0	0	148.5	148.5	0	0.0	0.8
		Caliente	Nye	0	4.7	308.5	313.2	0	261.0	0.7
		Caliente/LV	Clark	0	19.9	147.3	167.2	0	1,592.3[a]	2.1
		Caliente/LV	Lincoln	0	0	149.7	149.7	0	0.0	0.8
		Caliente/LV	Nye	0	0	59.4	59.4	0	0.0	0.0
		Caliente/Chalk Mountain	Lincoln	0	0	146.9	146.9	0	0.0	0.9
		Caliente/Chalk Mountain	Nye	0	0	135.3	135.3	0	0.0	0.0
	Jean	Jean/Sloan	Clark	0	41.9	88.6	130.5	0	1,592.3[a]	5.3
		Jean/Sloan	Nye	0	0	59.4	59.4	0	0.0	0.00

a. DIRS 155112-Berger 2000, pp.1 and 2 – This is a projected population along the Las Vegas beltway for the year 2020.

Table 3-18. Population counts by county for rail and heavy-haul truck implementing alternatives.

End Node	Origin	Implementing Alternative	County	Population Counts: Urban	Suburban	Rural	Total	Total Counts (1990)	Total Counts (2035)
Rail Implementing Alternatives									
Yucca Mountain	Eccles	Caliente/Chalk Mountain	Lincoln	0.00	0.00	21.26	21.26		
		Caliente/Chalk Mountain	Nye	0.00	0.00	0.00	0.00	21.26	28.22
		Caliente	Esmeralda	0.00	0.00	4.61	4.61		
		Caliente	Lincoln	0.00	0.00	20.45	20.45		
		Caliente	Nye	0.00	0.00	72.54	72.54	97.60	347.53
	Beowawe	Carlin	Esmeralda	0.00	0.00	6.90	6.90		
		Carlin	Eureka	0.00	0.00	17.55	17.55		
		Carlin	Lander	0.00	0.00	63.48	63.48		
		Carlin	Nye	0.00	0.00	708.79	708.79	796.73	3,202.22
	Jean	Jean	Clark	0.00	0.00	269.63	269.63		
		Jean	Nye	0.00	0.00	73.06	73.06	342.68	1,295.37
	Valley	Apex	Clark	0.00	0.00	51.69	51.69		
	Modified	Apex	Nye	0.00	0.00	0.04	0.04	51.73	188.10
Heavy-Haul Implementing Alternatives									
Yucca Mountain	Dry Lake	Apex/Dry Lake	Clark	0.00	45,929.2	1,227.1	47,156.3	171,649	
		Apex/Dry Lake	Nye	0.00	0.0	0.2	0.2	0.66	171,650
	Caliente	Caliente	Esmeralda	0.00	0.0	559.4	559.4	923	
		Caliente	Lincoln	0.00	0.0	491.7	491.7	654	
		Caliente	Nye	0.00	4,872.5	852.0	5,724.4	24,672	26,249
		Caliente/LV	Clark	0.00	45,929.2	1,215.2	47,144.4	171,606	
		Caliente/LV	Lincoln	0.00	0.0	501.7	501.7	667	
		Caliente/LV	Nye	0.00	0.0	0.2	0.2	0.66	172,274
		Caliente/Chalk Mountain	Lincoln	0.00	0.0	508.2	508.2	676	
		Caliente/Chalk Mountain	Nye	0.00	0.0	0.0	0.0	0.00	676
	Jean	Jean/Sloan	Clark	0.00	96,705.2	1,870.1	98,575.3	358,814	
		Jean/Sloan	Nye	0.00	0.0	0.2	0.2	0.66	358,815

Table 3-19. Distances and population densities by county for existing commercial rail lines in Nevada.

End Node	Implementing Alternative	County	Kilometers				Population Density (persons/km^2)		
			Urban	Suburban	Rural	Total	Urban	Suburban	Rural
Existing Rail Lines in Nevada									
Beowawe	Existing Rail NE#1	Eureka	0	0	31.5	31.5	0	0	0.1
	Existing Rail NE#1	Elko	0	11.3	218.1	229.3	0	463.4	2.0
	Existing Rail via Reno	Humboldt	0	6.4	103.8	110.2	0	431.4	5.5
	Existing Rail via Reno	Pershing	0	3.2	117.8	121.0	0	377.0	2.6
	Existing Rail via Reno	Lander	0	3.2	41.0	44.3	0	577.3	3.5
	Existing Rail via Reno	Eureka	0	0	22.7	22.7	0	0	0.1
	Existing Rail via Reno	Washoe	3.2	23.3	26.8	53.4	1953.2	517.6	14.9
	Existing Rail via Reno	Churchill	0	0	66.8	66.8	0	0	0
	Existing Rail via Reno	Storey	0	2.4	18.0	20.4	0	199.9	8.7
	Existing Rail via Reno	Lyon	0	3.2	14.7	18.0	0	586.9	12.9
Jean	Existing Rail Jean from South	Clark	0	0	41.7	41.7	0	0	1.0
	Existing Rail Jean from North	Clark	3.2	17.7	110.0	130.9	1879.6	750.6	0.8
	Existing Rail Jean from North	Lincoln	0	1.6	167.8`	169.4	0	294.3	0.8
Apex	Existing Rail Apex from North	Lincoln	0	1.6	167.8	169.4	0	294.3	0.8
	Existing Rail Apex from North	Clark	0	0	50.8	50.8	0	0	2.0
	Existing Rail Apex from South	Clark	3.2	17.7	100.9	121.8	1879.6	750.6	1.4
Caliente	Existing Routing to Caliente from N.	Lincoln	0.0	0.0	64.7	64.7	0	0	0.38
	Existing Routing to Caliente from S.	Clark	3.2	17.7	151.7	172.6	1879.6	750.6	1.6
	Existing Routing to Caliente from S.	Lincoln	0	1.6	103.1	104.7	0	294.3	0.9
Eccles	Existing Routing to Eccles from N.	Lincoln	0	0	56.3	56.3	0	0	0.03
	Existing Routing to Eccles from S.	Clark	3.2	17.7	151.7	172.6	1879.6	750.6	1.6
	Existing Routing to Eccles from S.	Lincoln	0	1.6	111.4	113.1	0	294.3	1.3
Dry Lake	Existing Routing to Dry Lake from N.	Lincoln	0	1.6	167.8	169.4	0	294.3	0.8
	Existing Routing to Dry Lake from N.	Clark	0	0	50.8	50.8	0	0	2.0
	Existing Routing to Dry Lake from S.	Clark	3.2	17.7	100.9	121.8	1879.5	750.6	1.4

Table 3-20. Population counts by county for existing commercial rail lines in Nevada.

End Node	Implementing Alternative	County	Population Counts (1990 Census Data) Urban	Suburban	Rural	Total	Escalated to the year 2035 Urban	Total Suburban
Beowawe	Existing Rail NE#1	Eureka	0.00	0.00	2.98	2.98	5	
	Existing Rail NE#1	Elko	0.00	8,352.76	693.97	9,046.74	21,260	21,265
	Existing Rail via Reno	Humboldt	0.00	4,443.05	909.80	5,352.86	11,027	
	Existing Rail via Reno	Pershing	0.00	1,941.32	489.69	2,431.00	7,880	
	Existing Rail via Reno	Lander	0.00	2,973.09	232.56	3,205.65	5,247	
	Existing Rail via Reno	Eureka	0.00	0.00	5.29	5.29	10	
	Existing Rail via Reno	Washoe	10,059	19,326	639	30,023	60,971	
	Existing Rail via Reno	Churchill	0.00	0.00	0.09	0.09	0	
	Existing Rail via Reno	Storey	0.00	772.23	248.73	1,020.96	2,548	
	Existing Rail via Reno	Lyon	0.00	3,022.54	303.44	3,325.98	10,734	98,417
Jean	Existing Rail Jean from South	Clark	0.00	0.00	67.58	67.58	246	246
	Existing Rail Jean from North	Clark	9,679.51	21,259.61	134.44	31,073.56	112,985	
	Existing Rail Jean from North	Lincoln	0.00	757.88	179.36	937.24	1,244	114,229
Apex	Existing Rail Apex from North	Lincoln	0.00	757.88	179.36	937.24	1,244	
	Existing Rail Apex from North	Clark	0.00	0.00	160.01	160.01	582	1,826
	Existing Rail Apex from South	Clark	9,679.51	21,259.61	229.69	31,168.81	113,331	113,331
Caliente	Existing Routing to Caliente from N.	Lincoln	0.00	0.00	32.25	32.25	43	43
	Existing Routing to Caliente from S.	Clark	9,679.51	21,259.61	389.70	31,328.82	113,913	
	Existing Routing to Caliente from S.	Lincoln	0.00	757.88	147.11	904.99	1,201	115,114
Eccles	Existing Routing to Eccles from N.	Lincoln	0.00	0.00	2.41	2.41	3	3
	Existing Routing to Eccles from S.	Clark	9,679.51	21,259.61	389.70	31,328.82	113,913	
	Existing Routing to Eccles from S.	Lincoln	0.00	757.88	176.95	934.83	1,241	115,154
Dry Lake	Existing Routing to Dry Lake from N.	Lincoln	0.00	757.88	179.36	937.24	1,244	
	Existing Routing to Dry Lake from N.	Clark	0.00	0.00	160.01	160.01	582	1,826
	Existing Routing to Dry Lake from S.	Clark	9,679.51	21,259.61	229.69	31,168.81	113,331	113,331

Table 3-21. Filename key-Attachment 33A.

Folder - LWT Cases	
File Name	**Description**
	LWT_Routing & Population Worksheets
Beltway - North	LWT routing using the Las Vegas Beltway
Beltway - South	LWT routing using the Las Vegas Beltway
Spaghetti – North	LWT routing using I-15 through Las Vegas from the north
Spaghetti – South	LWT routing using I-15 through Las Vegas from the south
Sgamile	Nevada LWT sensitivity case for Wendover via Las Vegas Beltway routing
Sgbmile	Nevada LWT sensitivity case for Wendover via U.S 95 routing
Sgcmile	Nevada LWT sensitivity case for Barstow via U.S. 95 routing
Sgdmile	Nevada LWT sensitivity case for Barstow via Nevada 160 routing
Sgemile	Nevada LWT sensitivity case for Needles via U.S. 95 routing
Sgfmile	Nevada LWT sensitivity case for Needles via Nevada 160 routing
DB_Input_LWT	Summary of LWT routing for the Yucca Mountain Transportation Access Database
	Existing_Comm_rail_FEIS (Routing & Population Data) Worksheets
Commercial Rail Link# Table	Table showing the link numbers for the commercial rail routes in Nevada used for the transportation analysis.
Commercial Rail Routes	Figure showing the link numbers for the commercial rail routes.
Crnwmile	LWT routing using I-15 through Las Vegas from the north
Commrail - SW	LWT routing using I-15 through Las Vegas from the south
Commrail – NE	Nevada LWT sensitivity case for Wendover via Las Vegas Beltway routing
Crs1mile	Nevada LWT sensitivity case for Wendover via U.S 95 routing
Crs2mile	Nevada LWT sensitivity case for Wendover via U.S 95 routing
Crs3mile	Nevada LWT sensitivity case for Barstow via U.S. 95 routing
Crs4mile	Nevada LWT sensitivity case for Barstow via Nevada 160 routing
Crs5mile	Nevada LWT sensitivity case for Needles via U.S. 95 routing
Crs6mile	Nevada LWT sensitivity case for Needles via Nevada 160 routing
DB_Input_Comm_Rail	Summary of LWT routing for the Yucca Mountain Transportation Access Database
Comm_Rail_Pop_Counts	
	HH _Alternatives_FEIS (Routing & Population Data) Worksheets
HH-Map	Worksheet showing maps and links for HH routes.
Apex	Worksheet with links, distances and pop densities for Apex/Dry Lake HH route
Jean-Sloan	Worksheet with links, distances and pop densities for Sloan/Jean HH route
Caliente	Worksheet with links, distances and pop densities for Caliente HH route
Caliente-Chalk Mt.	Worksheet with links, distances and pop densities for Caliente-Chalk Mountain HH route
Caliente-LV	Worksheet with links, distances and pop densities for Caliente-Las Vegas HH route
DB_Input_HH	Summary of HH routing for the Yucca Mountain Transportation Access Database
Noise Analysis	Population data for the noise region of influence
	Rail_Alternatives_FEIS (Routing & Population Data) Worksheets
Rail_Alt_Map	Table showing the link numbers for the rail alternative routes in Nevada used for the transportation analysis
Caliente	Worksheet with links, distances and pop densities for Caliente rail route
Carlin	Worksheet with links, distances and pop densities for Carlin rail route
Caliente-Chalk Mt.	Worksheet with links, distances and pop densities for Caliente-Chalk Mt. rail route
Jean	Worksheet with links, distances and pop densities for Jean rail route
Valley Modified	Worksheet with links, distances and pop densities for Valley Modified rail route
DB_Input_Rail	Summary of rail alternative routing for the Yucca Mountain Transportation Access Database

3.4 National and Nevada Population Escalation Factors

3.4.1 INTRODUCTION

This section presents the development of population escalation factors for national transportation and for transportation in Nevada. The transportation impacts estimated for the Yucca Mountain FEIS are based on analysis using 1990 U.S. Census data, 2000 U.S. Census data, and Bureau of Census projections for population growth to the year 2025. The analysis also uses projections of population along the Las Vegas Beltway for the year 2020 (DIRS 155112-Berger 2000, pp. 1 and 2). Because the transportation of SNF and HLW to Yucca Mountain is estimated to take 24 years under the Proposed Action and 38 years for Modules 1 and 2, the estimated impacts were escalated to the year 2035 to account for potential population growth and increase in transportation impacts.

In addition to the analyses presented in this calculation package, which are based on 1990 U.S. Census data and then escalated to 2035, a sensitivity analysis was conducted to determine the effect of using 2000 U.S. census data as the baseline and then escalating impacts to the year 2035. The results of that sensitivity analysis are discussed in Appendix H and are included in Attachment 34A in the folder entitled "2000 Census Sensitivity."

3.4.2 METHOD

Radiological public health and safety impacts resulting from incident-free movement and accidents in transporting radioactive materials include impacts that are estimated by calculating the integrated dose that would be received by populations along transportation routes. Key inputs to these calculations are estimates of the numbers of people living in the census blocks that are adjacent to the highways and railroads the shipments would use. For the Yucca Mountain DEIS, DOE used the HIGHWAY (DIRS 104780-Johnson et al. 1993, all) and INTERLINE (DIRS 104781-Johnson et al. 1993, all) computer programs to select and describe routes for analyzing transportation impacts. Once routes were selected, DOE used block-group data from the 1990 U.S. Census to estimate the number of people who live along each defined segment of routes. Computer program updates that incorporate 2000 Census data to HIGHWAY and INTERLINE were not available, although 2000 Census data became available in the spring of 2001.

Estimates of population dose radiological impacts are directly proportional to the density of the affected population. Therefore, estimates of incident-free doses to "off-link" populations along transportation routes and to the public living near truck and rail stops (calculated using the HIGHWAY and INTERLINE codes) can be linearly scaled to account for projected population growth using Bureau of the Census projections (www.census.gov/population/projections/state/stpjpop.txt) for state populations. Because the analysis of transportation accident risks can use the same along-route population data used to calculate incident-free population doses, estimates of accident risks can be scaled in the same way.

The population estimates in the State of Nevada were also escalated to the year 2035. The population escalation in Nevada is based on population forecasts provided by REMI using Clark County projections, Nye County projections, and State Demographer projections for remaining Nevada counties. The forecasts for Clark, Lincoln, and Nye Counties to the year 2035 were used along with the 1990 Census data for each county to estimate a population escalation factor (see Table 3-23). For all other counties in Nevada, State Demographer data, which provides population projections to the year 2010, were used along with a combined REMI forecast for these counties to estimate a 2035 population and an escalation factor. Estimates of population dose in Nevada are also directly proportional to the density of the affected population along routes. Therefore, as discussed above for impacts in all states except Nevada, the impacts can be linearly scaled in the same way to account for projected growth of populations in the State of Nevada.

3.4.3 ASSUMPTIONS

The routing in Nevada used the following assumptions:

- The region of influence for radiological health and safety impacts is 30 meters (98 feet) to 800 meters (2,625 feet) on each side of the route. This distance was used for estimating population density and population counts along each of the routes for use in the health and safety analysis.

- The region of influence for noise impacts is 2 kilometers (1.2 miles) on each side of the route. This distance was used for estimating population counts for each of the routes for use in the noise analysis.

- A population escalation factor for the years 1990 to 2035 was used to account for population growth along the route during the potential transportation campaign.

3.4.4 USE OF COMPUTER SOFTWARE/MODELS

Population escalation estimates were performed on a personal computer using the Windows 2000 operating system and Microsoft® Excel 2000 spreadsheets.

3.4.5 CALCULATION/ANALYSIS AND RESULTS

Table 3-22 presents the population projections for the 50 states and the District of Columbia for the year 2035. These population projections were based on projected population growth by the U. S. Census Bureau to the year 2025 (www.census.gov/population/projections/state/stpjpop.txt). The remaining years were extrapolated based on the percentage increase from 1990 to 2025.

For example, the Bureau of the Census reports that in 1990, the population of Alabama was 4,041,000 (DIRS 103156-Bureau of the Census 1997, all). The Bureau of the Census forecast for the Alabama population in 2025 is 5,224,000 (DIRS 152471-Bureau of the Census 2000, all), an increase of approximately 30 percent. The estimated incident-free dose to "off-link" populations, populations near truck and rail "stops," and radiological accident population dose-risk in Alabama from SNF and HLW shipments to Yucca Mountain would increase by a factor of 1.30. Doses to populations designated as "on-link" and at truck "stops" would not increase. "On-link" populations include members of the public in other vehicles that share the route. Although vehicle density might be assumed to increase, no data documenting such an increase are available. The number of people near the cargo at a rest and refuel truck stop would not increase. Populations at stops are discussed in Section 4.2.

Table 3-22. State population projections (in thousands). (1 of 2)

State	1990 Population	2000 Population (Projection)[a]	2000 Population (U.S. Census Data)[b]	2025 Population (Projection)[c]	Increase in pop per year (2025 Projection)	2035 Population (Based on 2025 Projections)	2035 Population Escalation (Based on 2025 Projections)
Alabama	4,041	4,451	4,447	5,224	30.92	5,529	1.37
Alaska	550	653	627	885	9.28	952	1.73
Arizona	3,665	4,798	5,131	6,412	64.56	7,390	2.02
Arkansas	2,351	2,631	2,673	3,055	16.96	3,267	1.39
California	29,760	32,521	33,872	49,285	670.56	57,341	1.93
Colorado	3,294	4,168	4,301	5,188	40.80	5,729	1.74
Connecticut	3,287	3,284	3,406	3,739	18.20	4,043	1.23
Delaware	666	768	784	861	3.72	914	1.37
D.C.	607	523	572	655	5.28	757	1.25
Florida	12,938	15,233	15,982	20,710	219.08	23,650	1.83
Georgia	6,478	7,875	8,186	9,869	79.76	10,978	1.69
Hawaii	1,108	1,257	1,212	1,812	22.20	1,989	1.79
Idaho	1,007	1,347	1,294	1,739	15.68	1,843	1.83
Illinois	11,431	12,051	12,419	13,440	55.56	14,364	1.26
Indiana	5,544	6,045	6,080	6,546	20.04	6,782	1.22
Iowa	2,777	2,900	2,926	3,040	5.60	3,122	1.12
Kansas	2,478	2,668	2,688	3,108	17.60	3,304	1.33
Kentucky	3,685	3,995	4,042	4,314	12.76	4,488	1.22
Louisiana	4,220	4,425	4,469	5,133	28.32	5,460	1.29
Maine	1,228	1,259	1,275	1,423	6.56	1,505	1.23
Maryland	4,781	5,275	5,296	6,274	39.96	6,695	1.40
Massachusetts	6,016	6,199	6,349	6,902	28.12	7,333	1.22
Michigan	9,295	9,679	9,938	10,078	15.96	10,497	1.13
Minnesota	4,375	4,830	4,919	5,510	27.20	5,871	1.34
Mississippi	2,573	2,816	2,845	3,142	13.04	3,301	1.28
Missouri	5,117	5,540	5,595	6,250	28.40	6,589	1.29
Montana	799	950	902	1,121	6.84	1,142	1.43
Nebraska	1,578	1,705	1,711	1,930	9.00	2,026	1.28
Nevada	1,202	1,871	1,998	2,312	17.64	2,616	2.18
New Hampshire	1,109	1,224	1,236	1,439	8.60	1,537	1.39
New Jersey	7,730	8,178	8,414	9,558	55.20	10,346	1.34
New Mexico	1,515	1,860	1,819	2,612	30.08	2,872	1.90
New York	17,990	18,146	18,976	19,830	67.36	21,334	1.19
North Carolina	6,629	7,777	8,049	9,349	62.88	10,250	1.55
North Dakota	639	662	642	729	2.68	736	1.15
Ohio	10,847	11,319	11,353	11,744	17.00	11,948	1.10
Oklahoma	3,146	3,373	3,451	4,057	27.36	4,408	1.40
Oregon	2,842	3,397	3,421	4,349	38.08	4,754	1.67
Pennsylvania	11,882	12,202	12,281	12,683	19.24	12,954	1.09
Rhode Island	1,003	998	1,048	1,141	5.72	1,249	1.24
South Carolina	3,487	3,858	4,012	4,645	31.48	5,114	1.47
South Dakota	696	777	755	866	3.56	879	1.26
Tennessee	4,877	5,657	5,689	6,665	40.32	7,100	1.46
Texas	16,987	20,119	20,852	27,183	282.56	30,741	1.81
Utah	1,723	2,207	2,233	2,883	27.04	3,180	1.85
Vermont	563	617	609	678	2.44	694	1.23
Virginia	6,187	6,997	7,079	8,466	58.76	9,135	1.48

Table 3-22. State population projections (in thousands). (2 of 2)

State	1990 Population	2000 Population (Projection) [a]	2000 Population (U.S. Census Data)[b]	2025 Population (Projection)[c]	Increase in pop per year (2025 Projection)	2035 Population (Based on 2025 Projections)	2035 Population Escalation (Based on 2025 Projections)
Washington	4,867	5,858	5,894	7,808	78.00	8,624	1.77
West Virginia	1,793	1,841	1,808	1,845	0.16	1,814	1.01
Wisconsin	4,892	5,326	5,364	5,867	21.64	6,121	1.25
Wyoming	454	525	494	694	6.76	730	1.61

a. Source: 103156-Bureau of the Census 1997, 1990 Census of Population and Housing (www.census.gov)

b. Source: 155872-Bureau of the Census 2000, 2000 Redistricting Data (P.L. 94-171) Summary File and 1990 Census.

c. Source: 152471-Bureau of the Census-2000, Projections of the Total Population of States: 1995 to 2025 (www.census.gov) (www.census.gov/population/projections/state/stpjpop.txt)

Population Escalation in Nevada

Estimates of population dose in Nevada are also directly proportional to the density of the affected population along routes. Therefore, as discussed above for impacts in all states except Nevada, the impacts can be linearly scaled in the same way to account for projected growth of populations in the State of Nevada.

The scaling uses Nevada State Demographer projections (see socioeconomic calculation package) and affected Nevada counties' demographic projections (see Table 3-23). In addition, for Clark County and the Las Vegas urban area, population estimates would increase by 842,737 to account for visitors in the year 2035 (136698-Riddel and Schwer 1999, all). Details on the REMI and Nevada State Demographer projections can be found in Attachment 34A (on the transportation calculation package compact disk).

Table 3-23. Factors for population increase (1990 - 2035) (See Table 3-24).

County	Population Increase 1990-2035
Carson City	2.08
Churchill	2.67
Clark[c]	3.64
Douglas	2.90
Elko	2.35
Esmeralda	1.65
Eureka	1.84
Humboldt	2.06
Lander	1.64
Lincoln[d]	1.33
Lyon	3.23
Mineral	1.21
Nye[e]	4.31
Pershing	3.24
Storey	2.50
Washoe	2.03
White Pine	1.19

Table 3-24. Filenames included in Attachment 34A

File Name	Description
National Escalation Fact ors	
Worksheets	
1990 Census Data	1990 U.S. Census data – state populations
2000 Census Data	2000 U.S. Census data – state populations
Beltway - South	LWT routing using the Las Vegas Beltway
Table 5	States ranking by population
Summary	Summary of state-by-state escalation factors
Nevada Escalation Fact ors	
Worksheets	
Clark-1990 Population Data	1990 Clark County REMI projections
Clark-2000 Population Data	2000 Clark County REMI projections
Nye-1990 Population Data	1990 Nye County REMI projections
Nye-2000 Population Data	2000 Nye County REMI projections
Lincoln-1990 Population Data	1990 Lincoln County REMI projections
Lincoln-2000 Population Data	2000 Lincoln County REMI projections
Rest of Nevada-2000 Population Data	2000 population data other counties in Nevada
NV_Demographer Data_2000	2000 Nevada State Demographer Data
U.S. Census Data	U.S. Census data for counties in Nevada
Summary	Summary of population escalation factors for counties in Nevada.

Based on Table 3-23, incident-free population doses and accident dose-risk for legal-weight truck shipments in southern Nevada (Clark County) will increase by a factor of 2.141 from values estimated using 1998 projections. This increase would not need to account for the population of visitors in Las Vegas because trucks carrying SNF and HLW would bypass the city's commercial and tourist center. These trucks would be required by DOT regulations to use the Las Vegas Beltway.

However, the adjustment would not account for higher rates of population growth that can be expected to occur in outlying areas along the new Las Vegas Beltway. For these areas, the estimate should assume that population densities will increase from their current rural character to that cited in Clark County 2000 (about 1,592 persons per square kilometer).

Table 3-24 lists the files related to National and Nevada population escalation that are included on the transportation calculation package compact disk.

4.0 INCIDENT-FREE HANDLING AND TRANSPORTATION

This section presents health and safety impacts of incident-free handling and transportation of SNF and HLW. Section 4.1 discusses cask loading and transfer at an IMT station. Sections 4.2 and 4.3 discuss the collective radiological impacts and radiological impacts on maximally exposed individuals (MEIs), respectively. Section 4.4 discusses nonradiological health and safety impacts.

4.1 Loadout and IMT Station Operations

4.1.1 INTRODUCTION

This section presents data used to estimate the impacts to involved workers (that is, those who would participate directly in the handling and loading of the transportation casks and conveyances) from incident-free operations during loadout operations at commercial nuclear power plants and during operations at an IMT station. These impacts include radiological (incident-free exposure to the shipping casks) and nonradiological (vehicle emissions impacts due to commuting workers). Accident-related impacts due to loadout operations were evaluated, including industrial safety impacts to involved and noninvolved workers and traffic fatalities. These impacts are presented in Section 5.0. The methodology and data used to evaluate impacts during loadout operations at commercial nuclear power plants were also used to evaluate impacts to workers at other facilities, including DOE sites with SNF and HLW. The Microsoft® Excel spreadsheet titled "Loadout Operations," included as Attachment 41A with this document, provides the details of the radiological and nonradiological impacts from loadout operations for commercial SNF, DOE SNF, HLW, GTCC waste, and SPAR waste.

This calculation package also presents data and information used to estimate the impacts of intermodal transfer of rail casks postulated to be shipped from 20 commercial nuclear power plant sites not served by a railroad.

4.1.2 METHOD

To estimate the radiological impacts of loading SNF and HLW at commercial and DOE facilities and impacts from IMT operations, the analysis used results from earlier DOE studies (DIRS 101747-Schneider et al. 1987, Sections 4 and 5; DIRS 104791-DOE 1992, all). These studies provide the most complete analyses available that estimate doses to workers and the public from loading and shipping SNF at commercial nuclear facilities and operations at an IMT. Equivalent information was not available for shipments from DOE facilities. However, because DOE and commercial operations would be similar, the analysis used the data provided by the studies to estimate the impacts of loading DOE SNF and HLW for shipment. The analysis combined the results of the earlier studies with the hypothesized characteristics of the shipping scenarios used in the EIS to develop impact estimates from shipments to the repository.

4.1.2.1 Radiological Impacts of Loading Operations at Commercial Sites

In 1987, DOE published its initial study of the estimated radiation doses to the public and workers resulting from the transport of SNF from commercial nuclear power reactors to a hypothetical deep geologic repository (DIRS 101747- Schneider et al. 1987, Sections 4 and 5). This study was based on a single set of SNF characteristics and a single split [30 percent/70 percent by weight; 900 metric tons (992 tons) uranium/2,100 metric tons (2,315 tons) uranium per year] between truck and rail conveyances. While this study was being performed, a monitored retrievable storage facility was proposed for inclusion in the SNF transportation system. DOE published its findings on additional radiological impacts on monitored retrievable storage workers in an addendum to the 1987 report (DIRS 104791-DOE 1992, all). The technical approaches and impacts summarized in these DOE reports were used to project involved worker impacts that would result from commercial at-reactor SNF loading operations. DOE did not provide a separate analysis of noninvolved worker impacts in these reports. For this analysis, DOE assumed that noninvolved workers would not receive radiation exposures from loading operations. This assumption is appropriate because noninvolved workers would be personnel with managerial or administrative support functions directly related to the loading tasks but at locations, typically in offices, away from areas where loading activities would take place.

In the DOE study, worker impacts from loading operations were estimated for a light-water reactor with pool storage of SNF. The radiological characteristic of the SNF in the analysis was 10-year-old, PWR fuel with an exposure history (burn-up) of 35,000 megawatt-days per metric ton. In addition, the reference PWR and BWR fuel assemblies were assumed to contain 0.46 and 0.19 metric tons of uranium, respectively, prior to reactor irradiation. These parameters for SNF are similar to those presented in DIRS 105155 (DOE 1999, Appendix A).

In the 1987 study, radiation-shielding analyses were done to provide information on (1) the conceptual configuration of postulated reference rail and truck transportation casks, and (2) the direct radiation levels at accessible locations near loaded transportation casks. The study also presented the results of a detailed time-motion analysis of work tasks that used a loading concept of operations. This task analysis was coupled with cask and at-reactor direct radiation exposure rates to estimate radiation doses to involved workers. Impacts to members of the public from loading operations had been shown to be insignificant [fraction of a person-millirem population dose (DIRS 104731-DOE 1986, p. 2.42, Figure 2.9)] and were eliminated from further analysis in the 1987 report. The at-reactor-loading concept of operations included the following activities:

1. Receiving the empty transportation cask at the site fence
2. Preparing and moving the cask into the facility loading area
3. Removing the cask from the site prime mover trailer
4. Preparing the cask for loading and placing it in the water-filled loading pit
5. Transferring SNF from its pool storage location to the cask
6. Removing the cask from the pool and preparing it for shipment
7. Placing the cask on the site prime mover trailer
8. Moving the loaded cask to the site fence where the trailer is connected to the transportation carrier's prime mover for offsite shipment

The results for loading operations are listed in Table 4-1.

The loading activities that the study determined would produce the highest collective unit impacts are listed in Table 4-2. As listed in this table, the involved worker collective radiation doses would be dominated by tasks in which the workers would be near the transportation cask when it contained SNF, particularly when they were working around the cask lid area. These activities would deliver at least 40 percent of the total collective worker doses. Worker impacts from the next largest dose-producing tasks (working to secure the transportation cask on the trailer) would account for 12 to 19 percent of the total impact. The impacts are based on using crews of 13 workers (the number of workers assumed in Schneider et al. [DIRS 101747-1987, Sections 4 and 5] study) dedicated solely to performing cask-handling work. The involved worker collective dose was calculated using the following formula:

$$\text{Collective dose (person-rem)} = A \times B \times C$$

where:

A	=	number of PWR or BWR SNF shipments being analyzed under each transportation scenario (see shipments calculation package)
B	=	number of transportation casks included in a shipment (set at 1 for both transportation scenarios)
C	=	involved worker-specific collective dose in person-rem/cask

Table 4-1. Principal logistics bases and results for the reference at-reactor loading operations.[a]

Parameter	Conveyance Rail[b]	Truck[c]	Total
Annual loading rate (MTU/year)[d]	2,100	900	3,000
Transportation cask capacity, PWR - BWR (MTU/cask)	6.5/6.70	0.92/0.93	NA[e]
Annual shipment rate (shipments/year)	320	970	1,290
Average loading duration,[f] PWR - BWR (days)	2.3/2.5	1.3/1.4	NA
Involved worker specific collective dose, PWR - BWR (person-rem/MTU)	0.06/0.077	0.29/0.31	NA
Involved worker specific collective dose, PWR - BWR (person-rem/cask)	0.39/0.52	0.27/0.29	NA

a. Source: DIRS 101747-Schneider et al. 1987, Sections 4 and 5.
b. 14 PWR and 36 BWR SNF assemblies per rail transportation cask.
c. 2 PWR and 5 BWR SNF assemblies per truck transportation cask.
d. MTU = metric tons of uranium.
e. NA = not applicable.
f. Based on single-shift operations; carrier drop-off and pick-up delays were not included.

Table 4-2. At-reactor reference loading operations—collective impacts to involved workers.[a, b]

	Rail		**Truck**	
Task description	**Collective Dose/MTU[c] (PWR - BWR)[d]**	**Percent of total impact**	**Collective Dose/MTU (PWR - BWR)**	**Percent of total impact**
Install cask lids; flush cask interior; drain, dry and seal cask	0.025/0.024	40/31	0.126/0.126	43/40
Install cask binders, impact limiters, personnel barriers	0.010/0.009	15/12	0.056/0.055	19/18
Load SNF into cask	0.011/0.027	17/35	0.011/0.027	4/9
On-vehicle cask radiological decontamination and survey	0.003/0.003	5/4	0.018/0.018	6/6
Final inspection and radiation surveys	0.002/0.002	4/3	0.016/0.015	5/5
All other (19) activities	0.011/0.012	19/16	0.066/0.073	23/23
Task Total	**0.062/0.077**	**100/100**	**0.29/0.31**	**100/100**

a. Source: DIRS 101747-Schneider et al. 1987, all.
b. Crew size is 13 involved workers.
c. Collective Dose/MTU = Collective dose (person-rem effective dose equivalent) per metric ton uranium.
d. PWR = pressurized-water reactor; BWR = boiling-water reactor

4.1.2.2 Radiological Impacts of DOE SNF and HLW Loading Operations

The methodology used to estimate impacts to workers during loading operations for commercial SNF was also used to estimate impacts of loading operations for DOE SNF and HLW. For shipments by truck and by rail, the analysis used the exposure factors for loading BWR SNF in casks at commercial facilities (person-rem per metric ton of uranium) (see Table 4-1). The factors, reported in person-rem per metric ton of uranium of SNF, were converted to person-rem per cask-load by multiplying by the number of metric tons of uranium that the study (DIRS 101747-Schneider et al. 1987, all) assumed would be contained in a cask. The analysis for the Yucca Mountain DEIS (DIRS 105155-DOE 1999, p. J-35) assumed that exposures to loadout operators would be independent of the cask contents and dependent only on cask handling, loading, and preparation for shipment. This assumption is based on a second assumption that operations and staff requirements to prepare casks to ship DOE SNF and HLW would be similar to those for commercial SNF. The analysis used the factor for BWR SNF (versus PWR SNF) because it would result in the largest estimates for dose per operation. Because commercial SNF is more radioactive (see Table 4-3), DOE anticipates that impacts from loading operations for DOE SNF and HLW would be smaller than those from loading operations involving commercial SNF. The crew size was assumed to be the same as that required for commercial SNF operations. Table 4-3 shows the average radioactive material content (curies) in a rail shipping cask as estimated in this analysis. Attachment A lists the isotope inventory for SNF and HLW. The average cesium-137 and actinide content were calculated from these data, as was the average curie content.

Table 4-3. Average cesium-137, actinide isotope, and total radioactive material content (curies) in a rail shipping cask.[a]

Material	Cesium-137	Actinides	Total
Commercial SNF	750,000	750,000	2,500,000
HLW	27,000	53,000[b]	180,000
DOE SNF (except naval SNF)	119,000	40,000	265,000
Naval SNF	450,000	28,000	1,100,000

a. Source: Attachment 41A
b. Includes plutonium can-in-canister with HLW.

4.1.2.3 Impacts at an IMT Station

The analysis assumed involved workers would be exposed to radiation during both inbound (to the repository) and outbound (to the generator sites) shipments. The analysis assumed that noninvolved workers would not be exposed to radiation. DOE used the same involved worker level of effort it used to analyze IMT worker industrial safety impacts (DIRS 105155-DOE 1999, pp. 6-21 to 6-24) to estimate collective involved worker radiological impacts (that is, 16 full-time equivalents [FTEs] per year). The collective worker radiation doses were adapted from a study (DIRS 104791-DOE 1992, all) of an SNF transportation system. This study estimated doses to involved workers for shipments from commercial power reactor sites. That study found that the collective worker doses that could be incurred during similar inbound and outbound transfer operations of a single cask loaded with commercial SNF and a single unloaded cask were approximately 26.525 and 0.883 person-millirem per cask, respectively, as listed in Table 4-4.

This analysis uses these inbound and outbound collective dose factors to calculate the involved worker impacts listed in Table 4-4 for the Proposed Action, Module 1, and Module 2 inventories. The number of inbound and outbound shipments for the Proposed Action, Module 1, and Module 2 inventories can be found in the Section 2.0 of this calculation package.

4.1.2.4 Nonradiological Impacts

Incident-free nonradiological impacts from loadout operations and IMT operations would result from vehicle emissions from commuting workers. The latent fatalities from vehicle emissions were estimated using factors developed in Section 4.4. Nonradiological impacts are discussed further in Section 6.0.

Table 4-4. Collective worker doses from transportation of a single cask.[a]

Inbound	Inbound Collective Dose	Outbound	Outbound Collective Dose
Receive transport vehicle and loaded cask. Monitor, inspect, unhook offsite drive unit, and attach onsite drive unit.	6.250	Receive transport vehicle and empty cask. Monitor, inspect, unhook offsite drive unit, and attach onsite drive unit.	0.000
Move cask to parking area and wait for wash down station. Attach to carrier puller when ready.	1.400	Move cask to parking area and wait for wash down station. Attach to carrier puller when ready.	0.542
Move cask to receiving and handling area.	0.092	Move cask to receiving and handling area.	0.008
Remove cask from carrier and place on cask cart.	4.333	Remove cask from carrier and place on cask cart.	0.217
Connect onsite drive unit and move cask to inspection area; disconnect onsite drive unit.	0.700	Connect onsite drive unit and move cask to inspection area; disconnect onsite drive unit.	0.033
Hook up offsite drive unit, move to gatehouse, perform final monitoring and inspection of cask.	13.750	Hook up offsite drive unit, move to gatehouse, perform final monitoring and inspection of cask.	0.083
Notify appropriate organizations of the shipment's departure.	0.000	Notify appropriate organizations of the shipment's departure.	0.000
Total	**26.525**	**Total**	**0.883**

a. Adapted from DIRS 104791-DOE 1992, all.

b. Collective Dose: units are person-millirem per cask)

4.1.3 ASSUMPTIONS

The analysis assumed that if DOE used a mostly legal-weight truck scenario, it would not construct a branch rail line or an IMT station in Nevada. Nonetheless, for the mostly legal-weight truck scenario, the analysis assumed DOE would use commercial IMT services at a railhead in Nevada to transfer rail casks containing naval SNF from railcars to heavy-haul trucks for transport to Yucca Mountain. For a mostly rail scenario in which a branch rail line was not constructed in Nevada, DOE would use an IMT station to transfer rail shipping casks containing SNF or HLW from railcars to heavy-haul trucks; the reverse operation would take place for empty casks coming from Yucca Mountain.

The following assumptions are used to estimate incident-free impacts for loadout and IMT operations:

- Latent fatalities from vehicle emissions were estimated using factors developed in Section 4.4 of this document, a round-trip distance of 37 kilometers (23 miles), and 251 trips per year per employee.
- The number of FTEs for loadout was estimated using:
    - The average loadout duration in days (listed in Table 4-1) for truck and rail loadout operations for both PWR and BWR fuel,
    - 8 hours per days,
    - 13 individuals per loadout operation, and
    - 2,000 hours per year.

- For IMT station construction, it was assumed that there would be 34 workers over 1.5 years of construction.

- For IMT station operation, it was estimated that there would be 34 workers over 24 years of operation for the Proposed Action or 38 years for Modules 1 and 2.

4.1.4 USE OF COMPUTER SOFTWARE/MODELS

A computer with the Microsoft® Windows 2000 operating system and Microsoft® Excel was used to calculate the incident-free impacts from loadout operations.

4.1.5 CALCULATION/ANALYSIS AND RESULTS

Details of the calculations of incident-free impacts from loadout operations are presented in a spreadsheet included on the transportation calculation package compact disk. The loadout operations impacts are included in a folder titled Loadout Operations.

Table 4-5 summarizes the incident-free impacts from loadout operations. Table 4-6 presents the incident-free radiological impacts from IMT operations. In addition, it is estimated that there would be a 0.054 latent fatality from vehicle emissions for commuter transportation for the construction and operation of an IMT station. Similarly, under Modules 1 and 2, there would be a 0.082 latent fatality.

Table 4-5. Summary of incident-free impacts from loadout operations.

	Proposed Action		Module 1		Module 2	
Proposed Action	**Mostly LWT**	**Mostly Rail**	**Mostly LWT**	**Mostly Rail**	**Mostly LWT**	**Mostly Rail**
Total shipments	52,786	10,725	105,685	18,241	108,544	18,933
Maximum dose to MEI (rem)[a]	12.0	12.0	12.0	12.0	12.0	12.0
Incremental risk of LCF for MEI	4.8E-03	4.8E-03	4.8E-03	4.8E-03	4.8E-03	4.8E-03
Collective dose (person-rem)	15,000	5,000	30,000	8,200	32,000	8,400
Estimate of LCFs in worker population	6.0	1.7	12.1	3.3	13	3.3
FTEs[b]	3,700	1,300	7,300	2,500	7,500	2,500
Total kilometers (commuting workers)	43,000,000	15,000,000	72,000,000	24,000,000	75,000,000	26,000,000
Vehicle emissions (fatalities)	0.06	0.02	0.38	0.13	0.39	0.14

a. The individual dose was assumed to be a maximum 12 rem for 24 years for the Proposed Action. The impacts assume worker rotation and other administrative actions would follow guidance similar to that in the DOE *Radiological Control Manual* (DIRS 104736-DOE 1994, Article 211) that would limit doses to individual workers to 500 millirem per year.

b. Level of effort expressed as the number of FTE labor-hour multiples; one FTE is equivalent to 2,000 hours worked in an occupational year. Impacts among the noninvolved workforce would be about 25 percent of the nonradiological impacts shown.

Table 4-6. IMT station incident-free radiological impacts (person-rem).

Proposed Action		Module 1		Module 2	
Mostly LWT[a]	**Mostly Rail**	**Mostly LWT[a]**	**Mostly Rail**	**Mostly LWT[a]**	**Mostly Rail**
8.2	260	8.2	500	9.7	520
Sites with Indirect Rail Access[b]					
	60		110		110

a. Impacts from the intermodal transfer of naval SNF; LWT = legal-weight truck.

b. The total number of shipments from sites with indirect rail access are 2,199 under the Proposed Action and 4,013 under Modules 1 and 2.

4.2 Doses from Incident-Free Transportation

4.2.1 INTRODUCTION

Casks containing SNF or HLW emit some ionizing radiation externally during routine incident-free transportation. Both gamma radiation and neutrons are emitted externally to the cask. Persons exposed to this externally emitted radiation would receive an external dose. The exposed population includes truck and rail crew, railyard workers, inspectors, and escorts, as well as members of the public, though the exposures would differ.

Calculation of these doses is the subject of this section. An overview of the calculation method is discussed in Section 4.2.2, though this section does not include any in-depth discussion of the RADTRAN 5 calculation model. The assumed input parameters used in calculating different exposures are discussed in Section 4.2.3. The RADTRAN model and its use of the input parameters are discussed in Section 4.2.4. Section 4.2.5 presents the unit risk factors developed by RADTRAN and the use of these unit risk factors with the Access database to calculate radiation doses from incident-free transportation.

4.2.2 METHOD

Radiation doses to receptors were calculated according to the information flow shown in Figure 4-1.

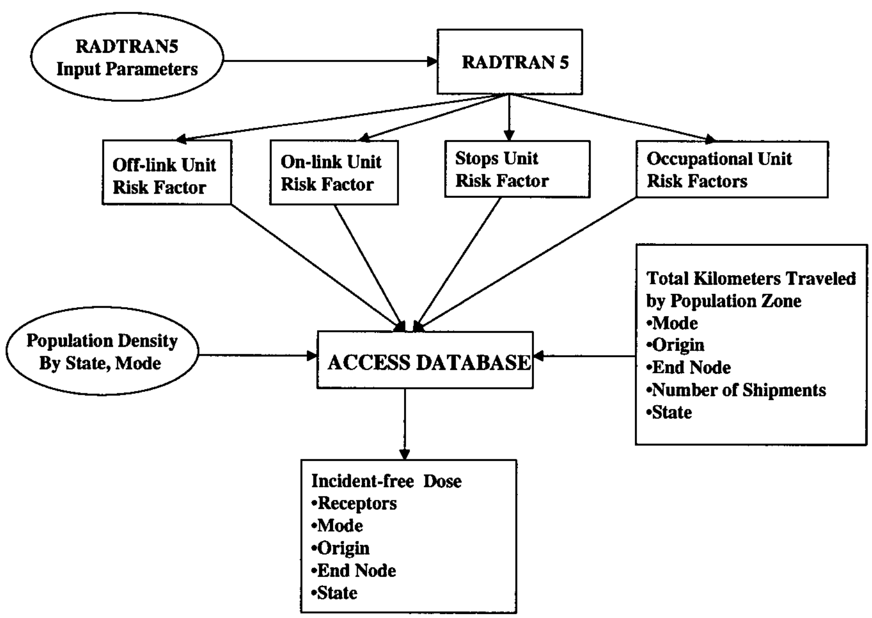

Figure 4-1. Information flow for calculating collective doses from incident-free transportation of SNF and HLW.

RADTRAN input parameters are presented in Tables 4-8 and 4-10 through 4-18. Unit risk factors are presented in Tables 4-20, 4-21, and 4-22. Incident-free doses are calculated by assuming that the external dose rate from the cask is the radiation source that exposes receptors at various distances from the cask. Calculations use a combination of RADTRAN 5 and the database. Appendix A provides a user guide for the transportation database. Exposure to both moving and stationary vehicles is considered. RISKIND is used to calculate doses to such receptors in some cases. In some instances, the regulatory limit of the external dose rate (10 millirem per hour at 2 meters from the vehicle) is used directly, and the dose is considered proportional to the inverse of the distance between receptor and cask. Incident-free occupational doses and doses to members of the general public ("public doses") are calculated separately. Separate calculations are performed for:

- *Off-link* population dose: members of the general public who reside along the transportation route or are pedestrians along the route, and are exposed to the moving vehicle carrying the cask
- *On-link* population dose: occupants of vehicles that share the transportation route with the SNF/HLW shipment while it is moving
- *Resident rest stop* dose: members of the public who live within a half-mile of a rest stop area where the truck stops
- *Crew* dose: truck crew members when the truck is moving
- *Walk-around crew* dose: truck crew members when the truck is stopped every 161 kilometers (100 miles) for a 10-minute "walk-around" inspection by crew
- *Truck stop* population dose: members of the public who are at rest and refueling stops when the truck carrying the shipment stops for refueling or to give the crew a rest
- *Resident walk-around stop* dose: members of the public who live within a half-mile of the route when the truck is stopped for a walk-around inspection
- [Rail] *classification stop* dose: rail yard workers, including crew and inspectors, loading and organizing (classifying) trains carrying SNF and HLW at the origin of each rail shipment and at the repository
- *Distance-dependent rail worker* dose: rail yard workers at intermediate rail stops along the route
- *Public rail stop* dose: members of the public resident within a half-mile of any rail stop
- *Escort* dose and *escort stop* dose: truck and rail escorts
- *Overnight stop* dose: guards at heavy-haul truck overnight stops

All of these exposures do not apply to all four modes of transportation: legal-weight truck , rail, heavy-haul truck, and barge. Exposures for each mode are calculated separately.

The incident-free dose to a receptor is an external dose and depends only on the dose rate external to the cask. It is not affected by the isotopic contents of the cask.

4.2.2.1 Relationship Between the Database and RADTRAN 5 calculations

RADTRAN 5 was used to calculate radiological unit risk factors, which were then used in the transportation database to calculate collective incident-free population doses. The theoretical basis and application of RADTRAN 5 are described thoroughly and in detail in the RADTRAN 5 Technical Manual (DIRS 155430-Neuhauser, Kanipe, and Weiner 2000, all) and the RADTRAN 5 User Guide (DIRS 150898-Neuhauser and Kanipe 2000, all) and may be viewed or downloaded at http://ttd.sandia.gov/risk/radtran.htm. This section briefly describes the RADTRAN model and deals only with specific details of the application of RADTRAN 5 in this analysis.

4.2.2.1.1 Calculation of doses from moving vehicles. RADTRAN 5 was used to calculate unit risk factors using the appropriate input parameters. Basic features of the RADTRAN model are (1) the cask and truck bed combination is modeled as spherically symmetric, and (2) the radiation source is the cask external dose rate but is modeled as an isotropic emission at the center of the sphere (DIRS 155430-Neuhauser, Kanipe, and Weiner 2000, p. 20) (i.e., a point-source model). The dose to a distant receptor is directly proportional to the dose rate buildup, which is the product of a buildup factor and an attenuation factor. For gamma radiation, this product is considered equal to unity in RADTRAN, because it is always less than or equal to one (DIRS 155430-Neuhauser, Kanipe, and Weiner 2000, pp. 29-30) . RADTRAN has included buildup and attenuation factors for external neutron emission.

The dose is inversely proportional to the *square of the distance* between the receptor and the center of the cargo (the truck bed). When the receptor is within about a cask length of the cask, as could be the case for crew and inspectors, the cask external dose rate is modeled as a line source, and the dose to the receptor is assumed to be inversely proportional to *the distance* between the receptor and the center of the cargo.

Dose is directly proportional to exposure time. The dose to a stationary receptor from a moving vehicle carrying radioactive cargo, the *off-link dose*, is modeled as inversely proportional to the speed of the vehicle.

For this analysis, the off-link dose can be expressed as the product of the unit risk factor, calculated by RADTRAN 5, and a factor calculated by the database. That is:

Dose = (database factor)*(unit risk factor) = DF*URF

The factors DF and URF are segments of the RADTRAN equations. For example, for the off-link population gamma and neutron doses (Equation 24, DIRS 155430-Neuhauser, Kanipe, and Weiner 2000, p. 38), the database and unit risk factors are, respectively,

$$DF_{off,gamma} = PD_L * NSH_L * DIST_L$$

$$URF_{off,gamma} = 4Qk_0 * \mathrm{DR_V} * \frac{1}{V_L} * FG_V\left[\int_{\min}^{SW} I_G(x)dx * RPD + \int_{SW}^{\max} I_G(x)dx * SF\right]$$

$$DF_{off,neutron} = PD_L * NSH_L * DIST_L$$

where:

$$URF_{off,neutron} = 4Qk * DR_V * \frac{1}{V_L} * FN_V \left[\int_{min}^{SW} I_N(x)dx * RPD + \int_{SW}^{max} I_N(x)dx * SF \right]$$

Q	=	a unit conversion factor
k_0	=	a package shape factor
DR_V	=	the transport index (TI) in mrem/hr
PD_L	=	the population density ½ mile on either side of the route along the particular link
V_L	=	the speed of the vehicle along the particular link
NSH_L	=	the number of shipments traveling along the link
$DIST_L$	=	the link length
FG_V and FN_V	=	the gamma and neutron fractions, respectively, of the TI
RPD	=	the ratio of pedestrian density to residential population density
SF	=	the shielding factor (no shielding is assumed in the EIS)

and the two integrals express the dose rate at a distance r from a spherically symmetric source of radiation using an inverse square ($1/r^2$) relationship and including the absorption and buildup factors.

The database substitutes tables of population densities, numbers of shipments along various routes, and lengths of various route segments for the variables PD_L, NSH_L, and $DIST_L$. With these variables equal to 1 in the RADTRAN input, RADTRAN is then used to calculate unit risk factors for rural, suburban, and urban segments of the various routes for each of the modes used (legal-weight truck, heavy-haul truck, rail, and barge). The resulting table of unit risk factors can then be multiplied by the applicable shipment kilometers to yield off-link incident-free doses for each segment of each route. The doses are then combined.

Crew doses are calculated in a manner similar to off-link doses.

Doses to occupants of other vehicles sharing the transportation corridor, the *on-link dose*, require a more complex set of assumptions regarding vehicle speed (DIRS 155430-Neuhauser Kanipe and Weiner 2000, p. 42). On-link doses are calculated by RADTRAN using Equations 31-34 of DIRS 155430 (Neuhauser, Kanipe, and Weiner 2000, pp. 42-45). The relative speed of vehicles moving in the same direction as the cask is assumed to be twice the cask vehicle speed when the vehicle is passing the cask, and zero if the vehicle is traveling in a lane next to the cask. In addition, the density of vehicles moving in the opposite direction is inversely proportional to the vehicle speed. Overall, the on-link dose is inversely proportional to the square of the vehicle speed (DIRS 155430-Neuhauser, Kanipe, and Weiner 2000, p. 42).

In calculating on-link doses, the database and unit risk factors are:

$$DF_{on} = NSHIP * DIST$$

$$URF_{on} = K * DR * \frac{N}{V^2} * \text{PPV} * \left\{ I' + \frac{1}{x}\left(V * I''\right) \right\}$$

where:

N = the vehicles/hour on the link (for Nevada transportation, part of this number was provided in the database and part in the unit risk factor

PPV = number of occupants of each vehicle

X = the minimum perpendicular distance to the adjacent vehicle

I′ and I″ are the appropriate integrals and expressions including dose rate, gamma/neutron fractions, integrals for the dose calculation, etc.

National per-kilometer on-link unit risk factors were calculated for each mode and shipment for each population zone, incorporating national average vehicle densities. Nevada per-kilometer on-link unit risk factors were calculated for each mode and shipment for each population zone by calculating for a vehicle density of one vehicle per hour. Rush-hour segments were accounted for by taking a weighted average of the rush hour and non-rush hour speeds and vehicle density ratios. As a result, the national on-link unit risk factors are considerably larger than the Nevada factors (see Section 4.2.5). The database then multiplies each unit risk factor by the route segment length, the number of shipments, and, in the case of Nevada routes, the appropriate vehicle density. The vehicle sharing the route with the radioactive cargo is not assumed to provide any radiation shielding for its occupants.

4.2.2.1.2 Calculation of doses at stops. RADTRAN 5 allows each stop, or type of stop, along a route to be modeled individually. The stops modeled in this analysis are:

- Legal-weight truck stops for rest and refueling. The dose to truck crew, members of the public at the stops, and residents near the stop are modeled.
- "Walk-around" inspection stops for legal-weight, overweight and heavy-haul trucks. The doses to crew members, inspectors, and residents near the stop are modeled.
- An overnight stop for heavy-haul trucks.
- Classification stops at the origin and destination of a rail trip. The doses to crew members, inspectors, and residents near the stop are modeled.
- In-transit classification stops for rail. The doses to crew members, inspectors, and residents near the stop are modeled.

The rest and refueling stop model used in the analysis for legal-weight truck shipments is shown in Figure 4-2.

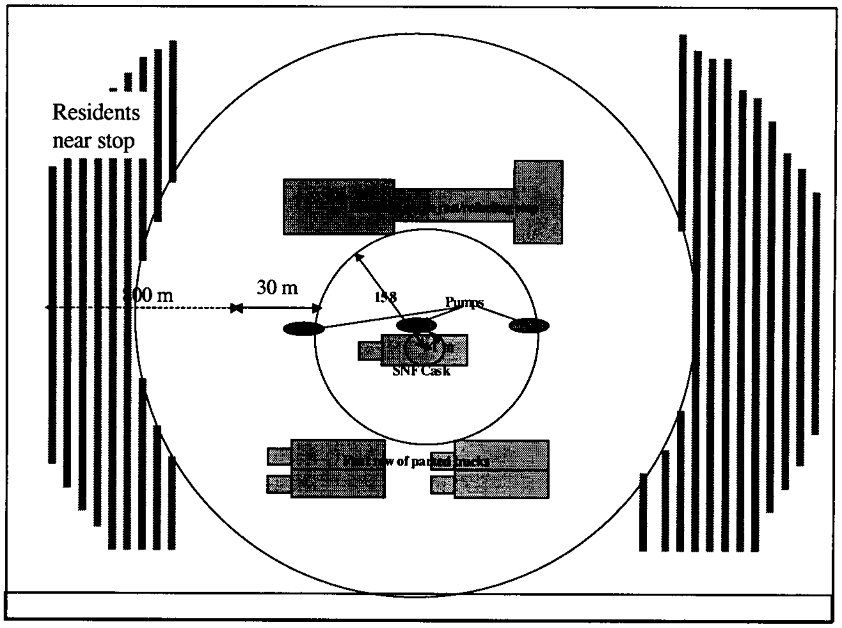

Figure 4-2. Rest/refueling stop model.

Exposure data for members of the public at rest-refueling stops are found in DIRS 152084-Griego, Smith, and Neuhauser (1996, all). The calculations used for the present analysis are summarized in Table 4-7.

Table 4-7. Data for rest/refueling truck stop model[a].

Number of observations	Outside persons[b,c]	Diameter= 2r meters	Area (m^2)	Number of persons x Observations	Area (m^2) x Observations	Outer exposure distance x Observations
3	6.9 +/-0.2	26.8	560.4	20.70	1,681.1	40.2
6	6.8+/-2.6	26.8	560.4	40.80	3,362.2	80.4
2	4.7+/-0.5	53.6	2,250.9	9.40	4,501.7	53.6
Average	6.4			70.90	9,545.0	15.8
Average persons /km^2				70.70/9,545 m^2= 7.426/m^2= 7,426/km^2		

a. From DIRS 152084-Griego, Smith, and Neuhauser 1996, all.

b. Only people outside of buildings at the stop are considered to be exposed.

c. Average number of people in the area at all times.

If members of the exposed population are at different distances from the radiation source, as observed in Griego et al. (DIRS 152084-1996, all), RADTRAN 5 requires the population density input of people per square kilometer. Such a population density is calculated as follows:

1. The area of the annular ring that constitutes the exposure area is calculated for each of the three observed stops by the following equation:

   $$\text{Exposure area} = \pi \times [(\text{outer radius})^2 - (\text{inner radius})^2]$$

2. The average number of unshielded people at each stop is divided by the exposure area of that stop to give a population density for each stop. The result is multiplied by 10^6 to convert from persons per square meter to persons per square kilometer: 1 square kilometer $= 10^6$ square meters.

3. The population density for each stop is multiplied by the number of observations of exposed persons made at that stop to give three weighted population densities.

4. The three weighted population densities are added, and the sum is divided by the total number of observations of exposed persons (11 observations in this case) to give the population density used in RADTRAN 5.

5. The weighted average number of people may then be calculated by multiplying the population density from Step 4 by the weighted average exposure area. This number is not used in RADTRAN 5 but is more intuitively understandable than a population density.

6. The "composite" outer radius was determined by solving the equation in Step 1, with the exposure area equal to the weighted average exposure area and the inner radius equal to 1.

Using the input parameters, RADTRAN 5 calculates a population dose per stop. Calculation of a unit risk factor, in units of person-rem per kilometer, for use with the transportation database requires an estimate of the number of stops per kilometer of travel, which in turn requires an estimate of how many miles the trucks travel between rest and refueling stops.

The dose to residents who live near places where the truck stops is calculated using the appropriate rural, suburban, or urban population density (depending on whether the stop is located in a rural, suburban, or urban area) and the same distance from the shipment as for the off-link dose calculation (30 to 800 meters [about 100 feet to one-half mile]).

In addition to the model for a rest and refueling stop, for which RADTRAN calculates the dose to a population distributed in an area around the source, the RADTRAN stop model allows calculation of dose to receptors at a fixed distance from the source. For example, doses to inspectors who are usually a meter from the vehicle are calculated this way.

Doses at stops are expressed as unit risk factors per kilometer of route length, for use in the database. The stop dose is calculated using Equations 37 and 38 or 39-41 of Neuhauser et al. (DIRS 155430-2000, p. 47); the result is divided by the average distance between stops, to yield a per-kilometer unit risk factor. A general unit risk factor derived from the equations in Neuhauser et al. is:

$$URF_{off} = K * DR * T * P * \{FG * TR_{r,G} + FN * TR_{r,N}\}(f(r,a))$$

where:

T = average stop time in hours

P = average number of exposed persons

f(r,a) = a function of the distance from, or area around, the cargo

TR = a function of distance from source to receptor; calculated by RADTRAN

To convert this number into a per-kilometer number that can be used in the database, the unit risk factor is divided by the average distance between stops, 845 kilometers for rest and refuel stops and 161 kilometers for "walkaround" inspection stops (see file "unitriskfactor_final" in Attachment 42A). The database then multiplies the resulting factor by the total distance from each origin to the repository, and by the number of shipments from each origin site.

The RADTRAN 5 rail stop model is based on the classification stop model described in Appendix B of Neuhauser et al. (DIRS 155430-2000). The occupational dose at a classification stop has been incorporated into RADTRAN 5, and the user inputs the number of classification stops per trip. In this analysis, a single classification stop occupational dose is calculated by RADTRAN 5 and input into the database. In the present analysis, there would be one classification stop at the origin site (or at the closest railhead if the origin site has no rail access) and a second classification stop at either the repository site or an IMT station. The database contains a classification stop for each state where there is an origin site, and for Nevada for the repository and for each IMT station. Doses to residents near the rail stops are calculated in the same way as doses to residents near truck stops.

4.2.3 ASSUMPTIONS

The model used to calculate collective population incident-free doses makes several general assumptions that apply to all transportation modes. The dose is assumed to be directly proportional to the number of shipments that move past the receptor (DIRS 155430-Neuhauser et al. 2000, p. 23). The collective incident-free population dose is proportional to the number of people exposed. For truck and rail transportation-related exposures, the exposed population is assumed to occupy an 800-meter (0.5-mile)-wide band on either side of the route, and the population density in this band is assumed to be the population density of the census block group that abuts or contains the route. Population assumptions and calculations are discussed in Sections 3.2 and 3.3.

Freeway truck speeds are assumed to be constant in the absence of rush-hour traffic. Buildings along the transportation route and vehicles sharing the route are assumed to provide no shielding from the cask external radiation.

National average one-way vehicle speeds were used to calculate the on-link dose for national legal-weight truck shipments and for heavy-haul truck shipments for those generator sites that have no rail access. Traffic counts from interstate and U.S. primary highway Nevada Department of Transportation traffic counters in each county are presented in Appendix F.

Doses at stops, the *stop* doses, are proportional to the exposure time and inversely proportional to the square of the distance and to the distance, for distant and nearby receptors, respectively. At rest stops, only exposure to people outside of buildings is considered. Residences near stops are assumed to provide no shielding.

Sections 4.2.3.1 through 4.2.3.4 present the assumptions and parameters used in RADTRAN 5 to calculate off-link and on-link doses. RADTRAN 5 includes a table of standard parameter values, as well as suggested values for other parameters. Unless a source of a parameter value is specified, the RADTRAN 5 standard value or suggested value is used.

4.2.3.1 Legal-weight truck input parameters

The assumptions and input parameters used in calculating incident-free doses from moving legal-weight and overweight truck shipments are presented in Table 4-8. National average traffic counts are included in this table. The Nevada Department of Transportation (DIRS 156930-NDOT 2001, all) provided traffic counts for highways in Nevada. The one-way average traffic counts for each county are shown in Table 4-9.

4.2.3.1.1 Parameters for calculating legal-weight truck stop doses. The rest and refueling stop model is shown in Section 4.2.2.1.2 (Figure 4-2). The receptors at stops modeled in the incident-free truck transportation analysis are:

- Members of the public at rest and refueling stops (truck stops)
- Residents of the area around the truck stops
- Truck crew performing the 161-kilometer (100-mile) "walk-around" inspections
- Residents along the route where the walk-around inspection takes place

Sprung et al. 2000 (DIRS 152476-p. 8-14) cites an average distance between rest and refuel stops of 1,286 kilometers (800 miles). However, this is based on trucks that carry two 303-liter (80-gallon) fuel tanks using half of their fuel between stops. The SNF trucks carry two 208-liter (55-gallon) tanks, and conservatively would use almost half of their fuel between stops (DIRS 152476-Sprung et al. 2000, p. 8-14). This analysis assumes that about 200 liters (52.5 gallons) would be used between stops (see "unitriskfactors_final" file in Attachemnt 42A). At 4.25 kilometers per liter, the truck would travel 845 kilometers (525 miles) before refueling.

The assumptions about package type, package dimensions, external dose rate, and gamma/neutron ratio are shown in Table 4-8. Additional assumptions used in analyzing the stop models are summarized in Tables 4-10 and 4-11.

Table 4-8. Assumptions and parameters used in calculating incident-free doses for legal-weight and overweight truck transportation.

Parameter	Parameter Value	Comments and Reference
Package		
Package type	Type B shipping cask	
Package dimension	5.2 m[a] long 1.0 m diameter	DIRS 152476-Sprung et al. 2000, p. 4-2. The material of the cask shell (steel-lead-steel or steel-depleted uranium-steel) does not affect the incident-free dose calculation.
Dose rate	10 mrem per hour, 2 m from side of vehicle (the regulatory maximum external dose rate)	The actual value used in the calculation is 14 mrem/hr at 1 m (3 ft) from the side of the vehicle – the same dose rate as 10 mrem/hr at 2 m (7 ft).
Fraction of emitted radiation that is gamma	0.5	For a G4 cask, if the neutron emission is less than the gamma emission, the ratio 0.5/0.5 is the most conservative gamma/neutron ratio for SNF and HLW.
Fraction of emitted radiation that is neutrons	0.5	
Crew		
Number of crew	2	
Distance from source to crew	3.1 m	
Dose to truck crew during travel	2 mrem/hr	This is the regulatory maximum.
Escorts (urban route segments only)		
Distance from source	60 m	
Dose rate	0.15 mrem/hr	Calculated using RISKIND for escort at 60 m from source for 1 hr
Route-specific parameters		
Rural	88 km/hr[b]	
Suburban	88 km/hr non-rush hour 44 km/hr rush hour	
Urban	88 km/hr non-rush hour 44 km/hr rush hour	
Fraction of the trip that is during rush hour		
Rural segments	0	
Suburban segments	0.1	
Urban segments	0.1	
Number of people per vehicle sharing route	2	
Minimum and maximum distances to exposed resident off-link population	30 to 800 m	
Population densities (persons per km^2)[c]		
Rural	(c)	
Suburban	(c)	
Urban	(c)	
One-way traffic count (vehicles per hour) on national highways		
Rural	470	
Suburban	780	1,560 during rush hour
Urban	2,800	5,600 during rush hour
One-way traffic count (vehicles per hour) on Nevada highways		
Rural	See Table 4-9	
Suburban	See Table 4-9	Doubled during rush hour
Urban	See Table 4-9	Doubled during rush hour

a. To convert meters to feet, multiply by 3.2808.
b. To convert kilometers (km) to miles, multiply by 0.62137.
c. Population densities along transportation routes were estimated using the HIGHWAY and INTERLINE computer programs (Sections 3.1.2, 3.2, and 3.3). These programs used 1990 Census data. Section 3.4 discusses population escalation to 2035.

Table 4-9. Average one-way traffic counts for Nevada counties.[a]

	Rural	Suburban	Urban
Carson	478	484	906
Churchill	76	233	0
Clark	364	1230	3,156
Douglas	300	472	0
Elko	78	151	0
Esmeralda	34	0	0
Eureka	89	0	0
Humboldt	103	195	0
Lander	18	136	0
Lincoln	20	29	0
Lyon	86	264	0
Mineral	50	97	0
Nye	17	101	0
Pershing	142	141	0
Storey	0	0	0
Washoe	471	650	1,959
White Pine	39	172	0
Average	**148**	**311**	**2,007**

a. Data developed from DIRS 156930-NDOT 2001, all. The traffic counts cited in the reference are two-way traffic counts.

Table 4-10. Assumptions and parameters used in calculating incident-free doses at truck stops.

Parameter	Parameter Value	Comments and Reference
Members of the public at truck stops		
Area of public exposure at the truck stop	Annulus of inner radius 1 m, outer radius 15.8 m[a]	
Number of members of the public exposed at the truck stop	6.4	This is entered in RADTRAN as 7,426 persons/km^2, derived from the data in Table 4-18.
Area of public exposure: residents near the truck stop	30 m to 800 m from source	
Crew		
Crew members exposed at truck stops	Two crew	One crew at 1 m from the outside edge of the vehicle, one crew in cab at 3.1 m. This is entered into RADTRAN as 2,304 persons/km^2 by the method illustrated by Table 4-18.
Stop time	0.32 hrs (19 min)	
Distance between stops	845 km[b] (525 mi)	

a. To convert meters to feet, multiply by 3.2808.

b. To convert kilometers (km) to miles, multiply by 0.62137.

c. Population densities along transportation routes were estimated using the HIGHWAY and INTERLINE computer programs (Sections 3.1.2, 3.2, and 3.3). These programs used 1990 Census data. Section 3.4 discusses population escalation to 2035.

Table 4-11. Assumptions and parameters used in calculating incident-free doses at walk-around stops.

Parameter	Parameter Value	Comments and Reference
Members of the public		
Area of public exposure	30 m to 800 m	Exposure distance on either side of the route.
Stop in rural area	(c)	
Stop in suburban area	(c)	
Stop in urban area	(c)	
Crew		
Number of crew members exposed	2	This is entered into RADTRAN as 2,304 persons/km^2. by the method illustrated by Table 4-18.
Stop time	0.17 hr (10 min)	
Distance between stops	161 km (100 mi)	

a. To convert meters to feet, multiply by 3.2808.
b. To convert kilometers (km) to miles, multiply by 0.62137.
c. Population densities along transportation routes were estimated using the HIGHWAY and INTERLINE computer programs (Sections 3.1.2, 3.2, and 3.3). These programs used 1990 Census data. Section 3.4 discusses population escalation to 2035.

Radiological inspections take place at the shipment origin and destination for the Proposed Action and Modules 1 and 2, and at every state boundary in the sensitivity cases. The inspector is assumed to be about 1 meter (3 feet) from the cask for about an hour. The inspection dose is calculated using RISKIND and is discussed further in Section 4.3.

4.2.3.2 Rail Input Parameters

4.2.3.2.1 Parameters for calculating doses from a rail car on a moving train. The assumptions used in calculating incident-free doses from moving rail shipments are presented in Table 4-12.

4.2.3.2.2 Parameters for calculating stop doses. The receptors at rail stops modeled in the incident-free analysis are:

- Residents of the area near all stops
- Rail crew and railyard workers at classification stops and stops en route.

The assumptions about the package type, package dimensions, external dose rate, and gamma/neutron ratio are shown in Table 4-12. The model is discussed at greater length in Section 4.2.2. Additional assumptions used in analyzing the doses to populations at stops are summarized in Tables 4-13 and 4-14.

Radiological inspections are assumed to take place at the shipment origin and destination for the Proposed Action and Modules 1 and 2, and at every state boundary for the sensitivity analyses. The inspector is assumed to be about a meter from the cask for about an hour. The inspection dose is calculated using RISKIND and is discussed further in Section 4.3. In calculating the occupational dose for rail transportation, the inspection dose is combined with the occupational classification yard dose as calculated by RADTRAN and with the dose to escorts as calculated by RISKIND.

Table 4-12. Assumptions and parameters used in calculating incident-free doses for rail transportation.

Parameter	Parameter Value	Comments and Reference
Package		
Package type	Type B shipping cask	
Package dimension	5.08 m[a] long 2.15 m diameter	DIRS 152476-Sprung et al. 2000, p. 4-2. The material of the cask shell (steel-lead-steel or monolithic steel) does not affect the incident-free dose calculation.
Dose rate	10 mrem per hr, 2 m from side of vehicle (the regulatory maximum external dose rate)	The actual value used in the calculation is 14 mrem/hr at 1 m from the side of the vehicle – the same dose rate as 10 mrem/hr at 2 m.
Package dimension for naval spent fuel	5.86 m long 2 m diameter	These are for naval SNF only and are from DIRS 152476-Sprung et al. 2000, p. 4-2. The material of the cask shell (monolithic steel) does not affect the incident-free dose calculation.
Dose rate for naval SNF	9 mrem per hour, 2 m from side of vehicle	The actual value used in the calculation is 12.56 mrem/hr at 1 m from the side of the vehicle – the same dose rate as 9 mrem/hr at 2 m.
Fraction of emitted radiation that is gamma	0.5	For a G4 cask, if the neutron emission is less than the gamma emission, the ratio 0.5/0.5 is the most conservative gamma/neutron ratio for SNF and HLW.
Fraction of emitted radiation that is neutrons	0.5	
Route Parameters		
Speed		
Rural	64 km/hr[b]	
Rural (Nevada)	51 km/hr	
Suburban	40.25 km/hr	
Urban	24 km/hr	
Number of people per vehicle sharing route	3	
Minimum and maximum distances to exposed resident off-link population	30 m to 800 m	
Population densities (persons per km^2)[c]		
Rural	(c)	
Suburban	(c)	
Urban	(c)	
One-way traffic count (vehicles per hour) on national highways		
Rural	1	
Suburban	5	
Urban	5	
Crew	--	The crew is assumed to be too distant and too well-shielded from external radiation from the cargo when the train is moving.

a. To convert meters to feet, multiply by 3.2808.

b. To convert kilometers (km) to miles, multiply by 0.62137.

c. Population densities along transportation routes were estimated using the HIGHWAY and INTERLINE computer programs (Sections 3.1.2, 3.2, and 3.3). These programs used 1990 Census data. Section 3.4 discusses population escalation to 2035.

Table 4-13. Assumptions and parameters used in calculating incident-free doses for rail classifications stops.

Parameter	Parameter Value	Comments and Reference
Occupational classification stop dose		
Classification stop dose	From DIRS 155430-Neuhauser et al. 2000, Appendix B	DIRS 155430-Neuhauser et al. 2000, calculates an occupational dose for a classification stop based on the dimensions and external dose rate of the cask. This dose is embedded in RADTRAN 5.
Classification stop time	30 hrs	
Number of classification stops per trip	Two	One at the trip origin and one at the terminus.
Inspectors	See Section 4.3.5	Calculated using RISKIND; calculation is discussed in Section 4.3.5.
Residents near classification stops		
Stop in rural area	(a, b)	
Stop in suburban area	(a, b)	
Area of public exposure	400 to 800 m[c] from source	

a. Population densities along transportation routes were estimated using the HIGHWAY and INTERLINE computer programs (Sections 3.1.2, 3.2, and 3.3). These programs used 1990 census data. Section 3.4 discusses population escalation to 2035.
b. Classification stops are in rural or suburban areas.
c. To convert meters to feet, multiply by 3.2808.

Table 4-14. Assumptions and parameters used in calculating incident-free doses at in-transit rail stops.

Parameter	Parameter values	Comments and reference
Occupational dose		
Classification stop dose	From DIRS 155430-Neuhauser et al. 2000, Appendix B	DIRS 155430-Neuhauser et al. 2000 calculates an occupational dose for a classification stop based on the dimensions and external dose rate of the cask. This dose is embedded in RADTRAN 5.
Distance-dependent worker exposure factor	0.0018 per km[a]	According to DIRS 155430-Neuhauser et al. 2000: the classification stop occupational dose is multiplied by a distance-dependent worker exposure factor to estimate the occupational dose at stops en route.
Residents near en route stops		
Stop time	0.033 hr/km	DIRS 155430-Neuhauser et al. 2000
Stop in rural area	(b)	
Stop in suburban area	(b)	
Stop in urban area	(b)	
Area of public exposure	30 m to 800 m[c]	Exposure distance on either side of the route.

a. To convert kilometers (km) to miles, multiply by 0.62137.
b. Population densities along transportation routes were estimated using the HIGHWAY and INTERLINE computer programs (Sections 3.1.2, 3.2, and 3.3). These programs used 1990 census data. Section 3.4 discusses population escalation to 2035.
c. To convert meters to feet, multiply by 3.2808.

4.2.3.3 Heavy-Haul Truck Input Parameters

4.2.3.3.1 Parameters for calculating doses from a moving heavy-haul truck.

Rail casks may be hauled by heavy-haul truck from an origin site to the nearest railhead and from an IMT station in Nevada to the repository. Heavy-haul trucks are assumed not to make refueling stops but to stop every 161 kilometers (100 miles) for a walk-around inspection. One overnight stop is assumed in Nevada for routes originating in Caliente because heavy-haul trucks can travel only during daylight hours. Heavy-haul trucks are accompanied by escorts. In the case of naval SNF, an additional naval escort accompanies the heavy-haul shipment. The assumptions used in calculating incident-free doses from heavy-haul truck shipments are presented in Table 4-15.

4.2.3.3.2 Parameters for calculating doses from heavy-haul trucks at stops.

The receptors at stops modeled in the incident-free heavy-haul transportation analysis are:

- Escorts performing the 161-kilometer (100-mile) "walk-around" inspections
- Crew during stops: crew remains in the truck while one escort performs the walk-around inspection. Other escort personnel remain in the escort vehicle.
- Guards at overnight stops: crew and escort personnel are assumed to be about 180 meters (591 feet) from the radioactive cargo and are shielded so that they receive no dose from the cargo. State police escorts are assumed to go home at night. Overnight stop areas are assumed to be located more than a half-mile from the nearest residence, so that no members of the public will receive any dose during overnight stops
- Residents along the route at "walk-around" inspection stops

The assumptions about the package type, package dimensions, external dose rate, and gamma/neutron ratio are those shown in Table 4-15. Additional assumptions used in analyzing the stop models are summarized in Tables 4-16 and 4-17.

Table 4-15. Assumptions and parameters used in calculating incident-free doses for heavy-haul truck transportation.

Parameter	Parameter Value	Comments and Reference
Package		
Package type	Type B shipping cask	
Package dimension	5.08 m[a] long 2.15 m diameter	DIRS 152476-Sprung et al. 2000, p. 4-2. The material of the cask shell (steel-lead-steel or monolithic steel) does not affect the incident-free dose calculation.
Dose rate	10 mrem per hr, 2 m from side of vehicle (the regulatory maximum external dose rate)	The actual value used in the calculation is 14 mrem/hr at 1 m from the side of the vehicle – the same dose rate as 10 mrem/hr at 2 m.
Package dimension for naval spent fuel	5.86 m long 2 m diameter	DIRS 152476-Sprung et al. 2000, p. 4-2. The material of the cask shell (monolithic steel) does not affect the incident-free dose calculation.
Dose rate for naval spent fuel	9 mrem per hour, 2 m from side of vehicle	The actual value used in the calculation is 12.56 mrem/hr at 1 m from the side of the vehicle – the same dose rate as 9 mrem/hr at 2 m.

Table 4-15. Assumptions and parameters used in calculating incident-free doses for heavy-haul truck transportation.

Parameter	Parameter Value	Comments and Reference
Fraction of emitted radiation that is gamma	0.5	For a G4 cask, if the neutron emission is less than the gamma emission, the ratio 0.5/0.5 is the most conservative gamma/neutron ratio for SNF and HLW.
Fraction of emitted radiation that is neutrons	0.5	
Crew		
Number of crew	3	
Distance from source to crew	30 m[a]	
Number of escort personnel	4	Two additional escort personnel for naval SNF shipments
Distance from source to escorts	60 m	
Speed		
Rural	40.25 km/hr[b]	
Suburban	40.25 km/hr	
Urban	40.25 km/hr	Heavy-haul trucks would not travel on urban routes
Number of people per vehicle sharing route	2	
Minimum and maximum distances to exposed resident off-link population	30 m to 800 m	
Population densities (persons per km^2)[c]		
Rural	(c, d)	
Suburban	(c, d)	
Urban	(c, d)	
One-way traffic count (vehicles per hour) on national highways		
Rural	470	
Suburban	780	
One-way traffic count (vehicles per hour) on Nevada highways		
Rural	See Table 4-9	The heavy-haul on-link unit risk factor normalized by factors derived from Table 4-9.
Suburban	See Table 4-9	
Urban	See Table 4-9	

a. To convert meters to feet, multiply by 3.2808.
b. To convert kilometers (km) to miles, multiply by 0.62137.
c. Population densities along transportation routes were estimated using the HIGHWAY and INTERLINE computer programs (Sections 3.1.2, 3.2, and 3.3). These programs used 1990 Census data. Section 3.4 discusses population escalation to 2035.
d. Population densities are provided for each county in Nevada.

Table 4-16. Assumptions and parameters used in calculating incident-free doses for heavy-haul truck stops.

Parameter	Parameter value	Comments and reference
Number of guards exposed	4	Neither crew members nor escorts will receive any exposure form the cargo.
Stop time	12 hrs	
Distance from guards to cargo	60 m[a]	
Residents near walk-around inspection stops	None	Overnight stops in locations where there are no residents within a half-mile on either side of the road.

a. To convert meters to feet, multiply by 3.2808.

Table 4-17. Assumptions and parameters used in calculating incident-free doses for heavy-haul truck walk-around stops.

Parameter	Parameter value	Comments and reference
Occupational doses		
Escort personnel	Four (plus two for naval spent fuel)	
Distance from escort personnel to cargo		One escort and one naval escort perform the walk-around inspection at 1 m[a] from the cargo. The other three (and the naval escort) remain 60 m from the cargo.
Crew	Three	Crew remain in the truck at 60 m from the cargo
Stop time	0.17 hr (10 min)	
Distance between stops	161 km[b] (100 mi)	
Residents near walk-around inspection stops		
Stop in rural area	(c)	
Stop in suburban area	(c)	
Stop in urban area	(c)	
Area of public exposure	30 m to 800 m	Exposure distance on either side of the route.

a. To convert meters to feet, multiply by 3.2808.
b. To convert kilometers (km) to miles, multiply by 0.62137.
c. Population densities along transportation routes were estimated using the HIGHWAY and INTERLINE computer programs (Sections 3.1.2, 3.2, and 3.3). These programs used 1990 Census data. Section 3.4 discusses population escalation to 2035.

4.2.3.4 Barge Input Parameters

Rail casks may be transported by waterway on barges for part of the route. Barges are assumed not to stop en route, and other ships or barges are assumed not to be close enough that their occupants would have on-link exposure.

The assumptions used in calculating incident-free doses from barge shipments are presented in Table 4-18.

Section 4.2.5 describes the unit risk factors and how they were generated, as well as the relationship between the unit risk factors and the Access™ transportation database (Appendix A).

Table 4-18. Assumptions and parameters used in calculating incident-free doses for barge transportation.

Parameter	Parameter Value	Comments and Reference
Package		
Package type	Type B shipping cask	
Package dimension	5.08 m[a] long 2.15 m diameter	DIRS 152476-Sprung et al. 2000, p. 4-2. The material of the cask shell (steel-lead-steel or monolithic steel) does not affect the incident-free dose calculation.
Dose rate	10 mrem per hour, 2 m from side of vehicle (the regulatory maximum external dose rate)	The actual value used in the calculation is 14 mrem/hr at 1 m from the side of the vehicle – the same dose rate as 10 mrem/hr at 2 m.
Fraction of emitted radiation that is gamma	0.5	For a G4 cask, if the neutron emission is less than the gamma emission, the ratio 0.5/0.5 is the most conservative gamma/neutron ratio for SNF and HLW.
Fraction of emitted radiation that is neutrons	0.5	
Crew		
Number of crew	2	
Distance from crew to cargo	10 m	
Speed		
Rural	8 km/hr[b]	
Suburban	8 km/hr	
Urban	8 km/hr	
Minimum and maximum distances to exposed resident off-link population	100 m to 1,000 m (1 km)	
Population densities (persons per km^2)[c]		
Rural	(c)	
Suburban	(c)	
Urban	(c)	

a. To convert meters to feet, multiply by 3.2808.
b. To convert kilometers (km) to miles, multiply by 0.62137.
c. Population densities along transportation routes were estimated using the HIGHWAY and INTERLINE computer programs (Sections 3.1.2, 3.2, and 3.3). These programs used 1990 Census data. Section 3.4 discusses population escalation to 2035.

4.2.4 COMPUTER MODELS AND SOFTWARE

In addition to the commercial software discussed in Section 1.1, RADTRAN 5 and the transportation database were used to perform the calculations discussed in this section. The theoretical basis and application of RADTRAN 5 are described thoroughly and in detail in the RADTRAN 5 Technical Manual (DIRS 155430-Neuhauser et al. 2000, all) and the RADTRAN 5 User Guide (DIRS 150898-Neuhauser and Kanipe 2000, all) and may be viewed or downloaded at http://ttd.sandia.gov/risk/radtran.htm. The database and its application are described in Appendix A.

4.2.5 CALCULATION/ANALYSIS AND RESULTS

4.2.5.1 RADTRAN Analysis and Results

RADTRAN input and output files, and the spreadsheets used to calculate unit risk factors, are in Attachment 42A on the compact disk accompanying this calculation package. The values for route segment length, population densities, and number of shipments for each origin-to-repository route are included in the Access database, and are employed as multiplying factors for the unit risk factors. All other factors in the equation are included in the RADTRAN 5 calculation of the appropriate unit risk factor. Thus:

- The off-link (and truck and barge crew) unit risk factor is per shipment, per-kilometer, per unit population density (persons per km^2). This unit risk factor is multiplied by the number of shipments and the appropriate combination of distance and population density to yield the off-link dose.

- The on-link unit risk factor is per-shipment and per-kilometer and is multiplied by the number of shipments and the appropriate distance, *not* by the population density.

The number of shipments was not included in the unit risk factor, but it was included in the Access database. Tables 4-19 through 4-21 present the per-shipment unit risk factors for incident-free transportation. In addition to the other multiplying factors cited in the tables, all of these unit risk factors are multiplied in the Access database by the number of shipments appropriate to the mode for the particular scenario (e.g., mostly rail proposed action, mostly truck Module 1, mostly truck Sensitivity Case B, etc.).

In Tables 4-19, 4-20, and 4-21, the term "E-0x" means 10^{-x} and "E+0x" means 10^{x}.

Table 4-19. Per-shipment unit risk factors for national incident-free transportation. (1 of 2)

Receptor	Type of Route Segment	Unit Risk Factors for Transportation Modes: Barge	Heavy Haul Truck	Rail	Legal-weight Truck
Public					
Off-link [rem per (persons per km^2) per km]	Rural	1.72E-07[a]	6.24E-08	3.90E-08	2.89E-08
	Suburban	1.72E-07	6.24E-08	6.24E-08	3.18E-08
	Urban	1.72E-07	6.24E-08	1.04E-07	3.18E-08
On-link (person-rem per km per vehicles/hr)	Rural		1.01E-04	1.21E-07	9.53E-06
	Suburban		7.94E-05	1.55E-06	2.75E-05
	Urban		2.85E-04	4.29E-06	9.88E-05
Residents near rest/refueling and walk-around stops [person-rem per (persons per km^2) per km]	Rural		3.96E-09	1.24E-07	5.50E-09
	Suburban		3.96E-09	1.24E-07	5.50E-09
	Urban		3.96E-09	1.24E-07	5.50E-09
Residents near rail classification stops (person rem/persons per km^2/km^2)	Suburban			1.59E-05	
Public including workers at rest/refueling stops (person-rem/km)	Rural				7.86E-06
	Suburban				7.86E-06
	Urban				7.86E-06
Workers					
Dose in moving vehicle (person-rem/km)	Rural	2.11E-06	5.54E-06		4.52E-05
	Suburban	2.11E-06	5.54E-06		4.76E-05
	Urban	2.11E-06	5.54E-06		4.76E-05
Classification stops at origin and destination (person-rem)	Suburban			4.64E-02[b]	1.80E-02[c]
Inspection stops at state borders in sensitivity cases (person-rem)	Suburban			3.74E-04[b]	1.80E-02

Table 4-19. Per-shipment unit risk factors for national incident-free transportation. (2 of 2)

Receptor	Type of Route Segment	Unit Risk Factors for Transportation Modes: Barge	Heavy Haul Truck	Rail	Legal-weight Truck
In-transit rail stops (person-rem/km)	Rural			1.45E-05	
	Suburban			1.45E-05	
	Urban			1.45E-05	
Walk-around inspection (person-rem/km)	Rural		6.27E-07		1.93E-05
	Suburban		6.27E-07		1.93E-05
	Urban		6.27E-07		1.93E-05

a. "E-07" is the same as "x 10^{-7}."

b. This unit risk factor combines the dose at classification stops, as calculated by RADTRAN, with the inspection and escort doses as calculated by RISKIND.

Table 4-20. Per-shipment unit risk factors for Nevada incident-free transportation.

Receptor	Type of Route Segment	Heavy Haul Truck	Rail	Legal-Weight Truck
Public				
Off-link (rem per (persons/km^2) per km)	Rural	6.24E-08	5.01E-08	2.89E-08
	Suburban	6.24E-08	6.24E-08	3.18E-08
	Urban	6.24E-08	1.04E-07	3.18E-08
On-link (person-rem/km)	Rural	2.15E-07	2.00E-07	2.03E-08
	Suburban	1.02E-07	1.55E-06	3.54E-08
	Urban	1.02E-07	4.29E-06	3.53E-08
Residents near rest/refueling and walkaround stops (rem per (persons/km^2) per km)	Rural	3.96E-09	1.24E-07	5.50E-09
	Suburban	3.96E-09	1.24E-07	5.50E-09
	Urban	3.96E-09	1.24E-07	5.50E-09
Residents near classification stops(rem per (persons/km^2)	Suburban		1.59E-05	
Public at rest/refuel stops (person-rem/km)	Rural			7.86E-06
	Suburban			7.86E-06
	Urban			7.86E-06
Worker				
Dose in moving vehicle (person-rem/km)	Rural	5.54E-06		4.52E-05
	Suburban	5.54E-06		4.76E-05
	Urban	5.54E-06		4.76E-05
Escort (person-rem/km)	Urban			1.79E-06
Classification and inspection stop at destination (person-rem)			4.64E-02	1.80E-02
Crew, walk-around inspection (person-rem/km)	Rural	6.27E-07		1.93E-05
	Suburban	6.27E-07		1.93E-05
	Urban	6.27E-07		1.93E-05
Escort, walk-around inspection (person-rem/km)	Rural	1.50E-05		
	Suburban	1.50E-05		
	Urban	1.50E-05		
Guards at overnight stops (person-rem)		2.62E-03		

Table 4-21. Per-shipment unit risk factors for incident-free transportation of naval SNF.

Type of Dose	Type of Route Segment	Heavy-Haul Truck	Rail
Doses to the public			
Off-link (person-rem per person-rem/ km^2 per km)	Rural		3.95E-08
	Suburban		6.33E-08
	Urban		1.05E-07
Nevada off-link (person-rem per person-rem/km^2 per km)	Rural	6.33E-08	5.08E-08
	Suburban	6.33E-08	6.33E-08
	Urban	6.33E-08	1.05E-07
On-link (person-rem per km)	Rural		1.23E-07
	Suburban		1.58E-06
	Urban		4.35E-06
Nevada on-link (person-rem/km)	Rural	1.48E-04	2.03E-07
	Suburban	1.14E-04	1.58E-06
	Urban	5.47E-04	4.35E-06
Near walk-around stops (person-rem per person-rem/km^2 per km)	Rural	4.02E-09	1.26E-07
	Suburban	4.02E-09	1.26E-07
	Urban	4.02E-09	1.26E-07
Near classification stops (person-rem per person-rem/km^2 per km)	Suburban		1.61E-05
Occupational doses			
Classification stop (person-rem)			7.69E-03
Truck crew in transit (person-rem/km)	Rural	5.26E-06	
	Suburban	5.26E-06	
	Urban	5.26E-06	
Crew at in-transit stops (person-rem/km)	Rural	6.34E-07	1.38E-05
	Suburban	6.34E-07	1.38E-05
	Urban	6.34E-07	1.38E-05
Escort at walk-around stop (person-rem/km)	Rural	1.34E-05	
	Suburban	1.34E-05	
	Urban	1.34E-05	
Guards at overnight stops (person-rem)		2.65E-03	
Navy escort at walk-around stop (person-rem/km)	Rural	1.33E-05	
	Suburban	1.33E-05	
	Urban	1.33E-05	

4.2.5.2 Offline Calculations

Excel spreadsheet calculations (see Section 1.1) were used to convert stop doses from the RADTRAN output to a per-kilometer dose. Spreadsheet calculations were also used to combine more than one RADTRAN and/or RISKIND output into a single unit risk factor. These calculations are shown in the files in Attachment 42A. As an example of such a calculation, the rural per-kilometer unit risk factors for residents near legal-weight truck stops and near walkaround inspection stops are combined into a single per-kilometer unit risk factor for rural residents near stops. The suburban and urban per-kilometer unit risk factors for residents near stops are similarly combined.

Similarly, the heavy-haul truck escort inspection stop unit risk factor combines the unit risk factor for the escort personnel inspecting with that for the personnel remaining in the escort vehicle.

4.2.5.3 Analysis and Results from the Access Database

This analysis uses the database described in Appendix A. The database (on compact disk) includes the unit risk factors discussed in Section 4.2.5.1. Results from the database calculations are presented in Section 7.5. Population doses are the result of a series of calculations performed by the database. An example is the following calculation of *off-link collective dose* for the *Caliente route* of the *mostly rail scenario*. The database does not necessarily perform these steps in the order given below, since both addition and multiplication are commutative.

1. Begin with the rural, suburban, and urban national rail off-link unit risk factors (national rail unit risk factors) from Table 4-19.

2. For each of the 77 routes from the origin site to the appropriate Nevada border, multiply the rural, suburban, and urban national rail off-link unit risk factors, respectively, by the rural, suburban, and urban population densities (found in file Attachments 31A and 32A and route segments distances for each state traversed. *The result will be the rural, suburban, and urban collective dose for one shipment for each state traversed to the Nevada border.*

3. Add the rural, suburban and urban collective doses for the states traversed for each route. *The result will be the collective dose for one shipment from each origin site to the Nevada border.*

4. For the Caliente example, repeat Steps 1 through 3 from the Nevada border to the repository for each Nevada county along the Caliente route, using the appropriate Nevada rail unit risk factors.

5. Add the national and Nevada collective doses for each route.

6. Multiply the result for each route from each origin (from Step 5) by the number of shipments from the origin site for that route. Shipment numbers are found in Section 2.5.

7. Add the resulting collective doses from Step 6. *The result is the total collective incident-free off-link rail dose for the Caliente route for the mostly rail scenario.*

The database user guide (Appendix A) provides the queries and intermediate tables for these calculations.

Because all shipments are included, this would constitute the collective incident-free population dose for the 24 years of the Proposed Action. The total collective incident-free dose to the public is the sum of the off-link, on-link and public stop doses. The total collective public dose for one alternative for the mostly rail scenario combines this sum with the sum of doses to the public for the truck-only sites. There are five alternatives for the mostly rail scenario, depending on the route through Nevada, but only one for the mostly truck scenario. For Modules 1 and 2, the number of shipments would be larger than for the Proposed Action.

A complete summary of the results from the database is given in Section 7.5. The RADTRAN files that are the basis of the incident-free calculation and are found on the accompanying compact disk in Attachment 42A are listed in Table 4-22.

Table 4-22. Files forming the basis for incident-free calculations.

File Name	File Size (bytes)	Date	File Description
unitrailga.in5	2,853	4/30/01	Rail input file
unitrailnew.out	13,882	4/30/01	Rail output file
usn_05.in5	2,239	5/8/01	Navy rail input file
usn_05.out	12,988	5/8/01	Navy rail output file
unitbarge.out	13,345	4/8/01	Barge output file
h_usn_05.in5	2,239	5/8/01	Navy heavy-haul input file
h_usn_05.out	12,988	5/8/01	Navy heavy haul output file
bnatcrewon.in5	2,830	5/3/01	Barge input file
hnatnev05.in5	2,503	5/8/01	Heavy-haul input file
hnatnev05.out	14,096	5/8/01	Heavy-haul output file
tnatnev04.in5	2,764	5/4/01	Legal-weight truck input file
tnatnev04.out	15,441	5/8/01	Legal-weight truck output file
unitriskfactors_final	581,000	10/11/01	Excel summary file

a. Files are included in Attachment 42A. Files *.in5 and *.out and RADTRAN 5 input and output files.

4.3 Incident-Free Doses to MEIs

4.3.1 INTRODUCTION

This section presents details of calculations of incident-free radiological impacts to MEIs proposed during the transportation of SNF and HLW to the Yucca Mountain repository. Specific information includes:

- Scenarios used to estimate radiological doses to MEIs
- Approach and data used to estimate radiological doses to shipment escorts
- Approach and data used to estimate radiological doses to vehicle inspectors

4.3.2 METHOD

The RISKIND code, along with assumptions regarding exposures to MEIs, was used to estimate exposures to MEIs. The scenarios for MEIs modeled for the Yucca Mountain FEIS are presented in Section 4.3.3. Table 4-23 presents the assumptions used for estimating the cask offset on the transport vehicle. Cask offset is the nearest distance from the external surface of a shipping cask's shield wall to the boundary planes of the side of a transport vehicle. The cask offset was used in the RISKIND computer program to estimate the level of radiation outside a cask and vehicle to which individuals could be exposed.

The analysis also estimated radiological impacts (doses) to the population of shipment escorts for both the mostly legal-weight truck scenario and the mostly rail scenario. Table 4-24 presents the assumptions made and shipment distances used in the calculations of these impacts for legal-weight truck, rail, and heavy-haul truck shipments.

Table 4-23. Cask offset distance.

Truck Cask	Length (in)	Length (m)	Diameter or Width (m)
Truck trailer	600	15.2	2.6
Cask[a]	200	5.1	0.7
Cask offset (width)[b]	**0.9**		
Cask offset (length)[b]	**5.1**		
Rail Cask	**Length (in) [a]**	**Length (m)**	**Diameter or Width (m)**
Rail car	720	18.3	3.0
Cask[a]	200	5.1	2.0
Cask offset (width)[b]	**0.5**		
Cask offset (length)[b]	**6.6**		
	Navy Cask		
Navy Rail Cask	**Length (in)[a]**	**Length (m)**	**Diameter or Width (m)**
Rail car	720	18.3	3.0
Cask[a]	231	5.9	2.2
Cask offset (width)[b]	**0.4**		
Cask offset (length)[b]	**8.1**		

a. Cask dimensions from DIRS 152476 (Sprung et al. 2000, Chapter 4).
b. Cask offset for the truck cask is the difference between the trailer width and the cask width or cask length and transport length divided by 2. For escort calculations, the offset was determined based on the end on view.

Table 4-24. Assumptions and data for estimating radiological impacts to shipment escorts

Mode	Legal-weight Truck	Rail	Heavy-haul truck
Number of escorts – urban area	Two escorts (one in separate vehicle) in urban areas.	Two	Three drivers Two police escorts
Number of escorts – suburban and rural	One (second driver)	One Navy –SNF - two	Two DOE escorts (For shipments of naval SNF, two Navy escorts – one additional vehicle)
Estimated dose rate 1 m from cask (mr/hr)	14	14	14
Exposure distance (m)	60	30	60
Exposure for 1 hr (rem)	1.10E-04	4.6E-04	1.10E-04
Exposure duration (hs)	Dependent on route traveled		
Speed (km/hr)			
Urban area	88 (44 during rush hour)	24	40
Suburban area	No escorts in suburban or rural population zones	40	40
Rural area		64	24
Traffic fatalities (fat/km)	1.00E-08	1.00E-08	1.00E-08

The analysis estimated impacts for escorts of shipments of naval SNF under the mostly legal-weight truck scenario for both the rail portion of travel to a node within Nevada and from a node within Nevada to Yucca Mountain by heavy-haul truck or rail. For shipments of naval SNF by rail, the analysis assumed two persons who would occupy a separate railcar for the full distance of travel would escort shipments.

4.3.3 ASSUMPTIONS

- For the Proposed Action, the duration of potential exposure is 24 years.
- Over 24 years for the Proposed Action, occupational workers could be involved with as many as 2,000 shipments under the mostly rail scenario and as many as 11,000 under the mostly legal-weight truck scenario. This is based on the total number of shipment presented in Section 2.5 (Table 2-1) and a work schedule of 1,800 hours per year. For example, under the mostly rail scenario, a truck stop worker is assumed to be exposed to (1,800 hrs/8,760 hrs)*1,079 shipments = ~220 shipments. This results in a dose of approximately 0.08 rem.
- For public exposures, it was assumed that an individual could be exposed to all shipments along a route. See Section 2.5 (Table 2-1) for the number of shipments for the mostly legal-weight truck and mostly rail scenarios.
- The dose risk conversion factors used are 0.0005 latent cancer fatality (LCF) per person-rem for public exposure and 0.0004 LCF per person-rem for worker exposure (DIRS 101836-ICRP 1991, p. 22).

The MEI is a hypothetical person who would receive the highest dose. Because different MEIs can be postulated for different exposure scenarios, the analysis evaluated the following exposure scenarios.

- *Crew Members.* In general, truck crew members would receive the highest doses during incident-free transportation (see discussion below). The analysis assumed that the members of crews would be limited to a total job-related exposure of 2 rem per year (DIRS 104736-DOE 1994, Article 211).
- *Inspectors (Truck and Rail).* Inspectors would be Federal or state vehicle inspectors. On the basis of information provided by the Commercial Vehicle Safety Alliance (DIRS 104597-Battelle 1998, all; DIRS 102209-CVSA 1999, all), the analysis assumed an average exposure distance of 1 meter (3 feet) and an exposure duration of 1 hour.
- *Railyard Crew Member.* For a railyard crew member working in a rail classification yard assembling trains, the analysis assumed an average exposure distance of 10 meters (33 feet) and an exposure duration of 2 hours (DIRS 101816-DOE 1997, p. E-50).
- *Resident.* The analysis assumed this MEI is a resident who lives 30 meters (100 feet) from a point where shipments would pass. The resident would be exposed to all shipments along a particular route (DIRS 101802-DOE 1995, p. I-52).
- *Individual Stuck in Traffic (Truck or Rail).* The analysis assumed that a member of the public could be 1.2 meter (4 feet) from the transport vehicle carrying a shipping cask for 1 hour. Because these circumstances would be random and unlikely to occur more than once for the same individual, the analysis assumed the individual to be exposed only once.
- *Resident near a Rail Stop.* The analysis assumed a resident who lives within 200 meters (660 feet) of a switchyard and an exposure time of 20 hours for each occurrence. The

analysis of exposure for this MEI assumes that the same resident would be exposed to all rail shipments to the repository (DIRS 101802-DOE 1995, p. I-52).

- *Person at a Truck Service Station.* The analysis assumed that a member of the public (a service station attendant) would be exposed to shipments for 49 minutes for each occurrence at a distance of 15.8 meters (51.8 feet) (DIRS 152084-Griego et al. 1996, all). The analysis also assumed this individual would work at a location where all truck shipments would stop.

As discussed above for exposed populations, the analysis converted radiation doses to estimates of radiological impacts using dose-to-risk conversion factors of the International Commission on Radiological Protection.

Transporting SNF to the Yucca Mountain site would require transport through Nevada on existing roads and highways. In addition, transporting SNF could involve use of a branch rail line that does not exist today. The proximity of existing structures that potentially could house an MEI have been determined. The MEIs in Nevada are listed below.

- The City of Las Vegas (DIRS 155112-Berger 2000, p. 104) identifies the MEI as being located 15 meters (50 feet) from an intersection. This individual would be exposed for 1 minute per shipment and an additional 30 minutes per year due to traffic delays. This MEI could apply to both legal-weight truck and heavy-haul truck transportation.

- DOE identified potential MEI locations as follows (based on their proximity to the proposed routes):

  - Residences are located approximately 5 meters (15 feet) from Highway 93 in Alamo (DIRS 155825-Poston 2001, p.10). The dose to a MEI at this location is estimated based on 10,000 heavy-haul shipments during 24 years.

  - The courthouse and fire station in Goldfield are 5.5 and 4.9 meters (18 and 16 feet), respectively (DIRS 155825-Poston 2001 p. 12) from the road. The dose to MEIs at this location is estimated assuming potential exposure to 10,000 heavy-haul truck shipments over 24 years.

  - The width of cleared area for a rail line would be 60 meters (197 feet); therefore, the closest resident would be at least 30 meters (98 feet) from a branch rail line. Most established communities are significantly removed from rail transportation routes (DIRS 155825-Poston 2001, p. 14).

  - The *Intermodal and Highway Transportation of Low-Level Radioactive Waste to the Nevada Test Site* (DIRS 155779-DOE 1999, VI pc-23, Table C-11) identifies an MEI as residing between Barstow, California, and the Nevada Test Site approximately 10.7 meters (35 feet) from a highway.

4.3.4 USE OF COMPUTER SOFTWARE/MODELS

The RISKIND computer program (DIRS 101483-Yuan et al. 1995, all) was used to estimate scenario-specific doses to MEIs for routine operations. The RISKIND code was originally developed for the DOE Office of Civilian Radioactive Waste Management specifically to analyze radiological consequences to individuals and population subgroups from the transportation of SNF and is used now to analyze the transport of other radioactive materials as well as SNF.

The RISKIND external dose model considers direct external exposure and exposure from radiation scattered from the ground and air. RISKIND was used to calculate the dose as a function of distance from a shipment on the basis of the dimensions of the shipment (millirem per hour for stationary exposures and millirem per event for moving shipments). The code approximates the shipment as a cylindrical volume source, and the calculated dose includes contributions from secondary radiation scatter from buildup (scattering by material contents), cloudshine (scattering by air), and groundshine (scattering by the ground). Credit for potential shielding between the shipment and the receptor was not considered.

4.3.5 CALCULATION/ANALYSIS AND RESULTS

The RISKIND input and output files used to estimate impacts to MEIs are provided separately on the compact disk included with this transportation calculation package. The RISKIND output presents estimated values for exposure to one shipment for each of the MEI scenarios. The results presented below are the product of these estimated exposures and the number of shipments that might pass or stop at the locations assumed for the MEIs. For example, the person-in-traffic is assumed to be exposed to only one shipment. Tables 4-25 and 4-26 present the impacts to MEIs under the mostly rail scenario and the mostly legal-weight truck scenario, respectively. Table 4-27 presents the impacts to MEIs in Nevada.

Table 4-25. Impacts to MEIs under the mostly rail scenario.[a]

Mostly Rail Scenario - Proposed Action				
Rail Impacts	**Category**	**Dose (rem) One Shipment[b]**	**Hypothetical MEI Exposure[c]**	**LCFs**
	Crew Members	1.70E-02	48.0[d]	0.02
	Inspectors	1.70E-02	34	0.013
	Rail Yard Crew Member	2.10E-03	4.2	0.002
	Resident	1.70E-07	0.0016	0.000001
	Person in Traffic	1.50E-02	0.015	0.000008
	Resident near a Rail Stop	3.00E-05	0.29	0.000145
Truck Impacts	**Category**	**Dose (rem) One Shipment[b]**	**Hypothetical MEI Exposure[c]**	**LCFs**
	Crew Members	1.80E-02	4.0	1.6E-03
	Inspectors	1.80E-02	4.0	1.6E-03
	Resident	1.10E-07	0.00012	5.93E-08
	Person in Traffic	1.60E-02	0.02	8.00E-06
	Truck Stop Worker	3.40E-04	0.08	3.7E-05

a. See Table 4-28 for the separately attached files where the calculations of impacts to MEIs can be found.
b. Calculated with the RISKIND code.
c. See Section 4.3.3 for the number of shipments for each exposure category.
d. Exposure from approximately 2,800 shipments.

Table 4-26. Impacts to MEIs under the mostly legal-weight truck scenario.[a]

Mostly Truck Scenario				
Truck Impacts	**Category**	**Dose (rem) One Shipment[b]**	**Hypothetical MEI Exposure[c]**	**LCFs**
	Crew Members	1.80E-02	48.0[d]	1.9E-02
	Inspectors	1.80E-02	48.0[d]	7.8E-02
	Resident	1.10E-07	0.0058	2.9E-06
	Person in Traffic	1.60E-02	0.016	8.0E-06
	Truck Stop Worker	3.40E-04	3.7	1.8E-03
Rail Impacts	**Category**	**Dose (rem) One Shipment[b]**	**Hypothetical MEI Exposure[c]**	**LCFs**
	Crew Members	1.70E-02	1.0	4.2E-0
	Inspectors	1.70E-02	1.0	4.2E-04
	Rail Yard Crew Member	2.10E-03	0.13	6.5E-05
	Resident	1.70E-07	0.0001	2.6E-08
	Person in Traffic	1.50E-02	0.015	7.5E-06
	Resident near a Rail Stop	3.00E-05	0.00900	4.5E-06

a. See Table 4-28 for the separately attached files where the calculations of impacts to MEIs can be found.
b. Calculated with the RISKIND code.
c. See Section 4.3.3 for the number of shipments for each exposure category.
d. Exposure from approximately 2,700 shipments.

Table 4-27. Impacts to MEIs in Nevada.[a]

Nevada MEIs					
	Category	**Dose (rem) One Shipment[b]**	**Hypothetical MEI Exposure[c]**	**Total (rem)**	**LCFs**
LWT MEI or Heavy-haul	Berger Report (LWT) 1 min	1.00E-05	0.528		
	Berger Report (LWT) – 30 min[d]	2.50E-04	0.01		
	Total Berger Report MEI	2.60E-04	0.53	0.53	2.7E-04
	LLW Report	3.80E-07	0.02	0.02	1.0E-05
Heavy-haul	Alamo	2.6E-06	0.03	0.03	1.3E-05
Heavy-haul	Goldfield courthouse	2.8E-06	0.03	0.03	1.4E-05
Heavy-haul	Goldfield fire station	3.0E-06	0.03	0.03	1.4E-05
	Goldfield MEI	0.00	0.03	0.03	1.4E-05
Rail	Resident in Nevada	1.70E-07	0.002	0.0016	8.2E-07

a. See Table 4-28 for the separately attached files where the calculations of impacts to MEIs can be found.
b. Calculated with the RISKIND code.
c. See Section 4.3.3 for the number of shipments for each exposure category.
d. This dose is assumed to be 30 minutes per year due to traffic delays (See Section 4.3.3).

In addition, the analysis estimated impacts to truck inspectors. It was assumed that the legal-weight truck shipments would be inspected at both the origin and destination as recommended by the Commercial Vehicle Safety Alliance. Using data presented in Tables 4-23 and 4-24 above, the analysis estimated that an individual truck inspector would receive a dose of 1.8E-02 rem per inspection based on an exposure time of 1 hour at a distance of 1 meter (3.3 feet).

Also included separately on compact disk are the RISKIND input and output files containing additional detailed information used in estimating impacts to MEIs.

The spreadsheets and computer output in Table 4-28 list data and results of calculations of incident-free impacts of transporting SNF and HLW to Yucca Mountain.

Table 4-28. Spreadsheets and computer output.

Spreadsheet/ Computer Output	Description
Incident-free MEIs_FEIS	
Worksheet Title	
Proposed Action	This worksheet presents data for the mostly legal-weight and mostly rail scenarios used to calculate incident-free impacts.
Nevada_MEIs	This worksheet provides the calculation of Nevada-specific MEIs.
RISKIND Nev	RISKIND computer program input and output used to estimate doses to MEIs in Nevada.
RISKIND Rail MEIF	RISKIND computer program input and output (three sheets) used to estimate doses to MEIs for rail shipments.
RISKIND LWT MEIF	RISKIND computer program input and output used to estimate doses to MEIs for legal-weight truck shipments. Calculation of unit risk factors for escorts (rem/km of travel).
LLW MEI	RISKIND computer program input and output used to estimate doses to MEIs for LLW shipments in Nevada.

4.4 Vehicle Emission Unit Risk Factors

This section describes the development of unit risk factors used to estimate the impacts from exhaust and fugitive dust emissions from highway and rail vehicle traffic in the Yucca Mountain FEIS. These unit risk factors have units of fatalities per kilometer per person per square kilometer.

4.4.1 INTRODUCTION

The Vehicle Emission Unit Risk Factors for Transportation Risk Assessments (DIRS 151198-Biwer and Butler 1999, all) presents unit risk factors for estimating vehicle emissions and the resulting health effects (fatalities) from truck and rail transportation. Four changes were made in the unit risk factors presented in Biwer and Butler to estimate unit risk factors for the Yucca Mountain FEIS:

1. *Fugitive dust emission factor*: An emission factor is the mass of a pollutant per kilometer put into the air by vehicle traffic. Biwer and Butler used the paved road fugitive dust emission factor equation from Section 13.2.1, Volume 1, *Supplement D* to *Compilation of Air Pollutant Emission Factors* (AP-42) (DIRS 155786-EPA 1997) to estimate fugitive dust emission factors for individual vehicle weight classes. As stated in Section 13.2.1.3 of AP-42, "one emission factor should be calculated to represent the fleet average weight of all the vehicles traveling the road," and the emission factor equation "is not intended to be used to calculate a separate emission factor for each vehicle weight class." In the FEIS, the emission factor was based on the fleet average weight.

2. *Diesel exhaust emission factor*: Biwer and Butler used diesel exhaust emission factors for trucks operating in 1995. The FEIS used information presented in the *Motor Vehicle-Related Air Toxics Study* (DIRS 155780-EPA 1993, all) to estimate diesel exhaust emission factors for truck operations in the year 2010, which is when shipments to the repository would begin.

3. *Mortality rate used to estimate health effects*: The PM_{10} risk factor used in Biwer and Butler was calculated using a baseline mortality rate of 0.008. This appears to be a crude rate, which is influenced by age differences in population composition. In the FEIS, an age-adjusted mortality rate of 0.005 was used to calculate a PM_{10} risk factor. This eliminated the influences of age differences in the population composition.

4. *PM_{10} risk factor*: The PM_{10} risk factor used in Biwer and Butler was based on an upper-bound risk factor from Ostro and Chestnut (DIRS 152600-1998, all), who also presented a lower-bound estimate and a central estimate. In the FEIS, the central estimate from Ostro and Chestnut was used to avoid compounding of conservative assumptions, providing a more realistic estimate of impacts.

4.4.2 METHOD

The unit risk factors were estimated by modifying the data and analyses presented in Biwer and Butler (DIRS 151198-1999, all) to account for the changes discussed in Section 4.4.1.

4.4.3 ASSUMPTIONS

Truck tractor emissions for legal-weight, over-weight, and heavy-haul truck shipments of SNF, HLW, construction materials, office and laboratory supplies, mail, wastes, and commuter buses would be the same as for Class VIIIB heavy-duty diesel vehicles for a fleet operational in 2010. Heavy-duty, class VIIIB diesel vehicles have a gross vehicle weight greater than 14,969 kilograms (33,000 pounds) (see DIRS 151198-Biwer and Butler 1999, Table I).

Data for light-duty diesel vehicles (truck class light-duty diesel vehicles; see DIRS 151198-Biwer and Butler 1999, Tables VI and VII) were used to represent automobiles (diesel particulate emissions were assumed to be 0.0 for automobiles because automobiles use gasoline engines). The unit risk factors for automobiles were used for escorts and commuters.

4.4.4 USE OF COMPUTER SOFTWARE/MODELS

Microsoft® Excel 1997 was used to perform the calculations for this analysis. Microsoft® Excel 1997 spreadsheets may be used on a personal computer using the Windows 95, Windows NT, or Windows 2000 operating system. The calculations were verified through inspection.

4.4.5 CALCULATION/ANALYSIS AND RESULTS

The analyses presented here incorporate by reference, with modifications and updates, the analyses and results presented in Biwer and Butler (DIRS 151198-1999, all).

4.4.5.1 Revisions to Fugitive Dust Emission Factors

Biwer and Butler (DIRS 151198-1999, Section 2.3) presented the following equation used to estimate the emission factor for fugitive dust emissions from passing vehicles.

$$E = k(sL/2)^{0.65}(W/3)^{1.5}$$

where:

E = particulate emission factor (g/vehicle-km traveled [VKT])

k	=	base emission factor for particle size range (1.1 g/VKT for 2.5 μm particles or 4.6 g/VKT for 10 μm particles)
sL	=	road surface silt loading (g/m^2), and
W	=	average weight (tons) of the vehicles traveling the road.

The equation was taken from AP-42, Section 13.2.1 (DIRS 155786-EPA 1997). The equation is intended to estimate fugitive dust emissions from traffic on highways used by a mix of vehicles. The W term in the equation is intended to be the fleet average weight of all vehicles traveling the road. Section 13.2.1.3 of AP-42 states that the equation "is not intended to be used to calculate a separate emission factor for each vehicle weight class" and "one emission factor should be calculated to represent the fleet average weight of all the vehicles traveling the road." Nonetheless, Table VI in Biwer and Butler presented fugitive dust emission rates calculated separately for each class of truck using the weights for each class also reported in Table VI. Using the equation listed above, along with values for variables presented by Biwer and Butler and a vehicle weight of 36,000 kilograms (40 tons) yields:

K	=	1.1 g/VKT (2.5 μm particles)
SL	=	0.015 g/m^2
W	=	40 tons
E	=	2.226 g/km for 2.5 μm particles

This value was presented for Class VIIIB vehicles in Column 4 of Table VI of Biwer and Butler (DIRS 151198-1999). For 10 μm particles, the emission factor was 9.310 grams per kilogram. This value was presented for Class VIIIB vehicles in Column 4 of Table VII of Biwer and Butler.

When the average vehicle weight (3,348 kilograms [3.69 tons]) based on the total transportation fleet projected to use national highways in 2010 was used, the emission factor for 2.5-μm particles was 0.062 gram per kilogram and the emission factor for 10-μm particles was 0.26 gram per kilogram (see Table 4-29). In the FEIS, this emission factor was also used for railcars. Biwer and Butler (DIRS 151198-1999, all) cite evidence that the emission factor for railcars might be 10 percent of the emission factor for vehicles, so this probably overestimates impacts.

4.4.5.2 Revisions To Diesel Exhaust Emission Factor

The following analysis updates diesel exhaust emissions data used by Biwer and Butler to estimate diesel exhaust emission factors. The updates make use of projections presented in the *Motor Vehicle-Related Air Toxics Study* (DIRS 155780-EPA 1993, all) for vehicle fleet makeup and vehicle miles traveled for the year 2010.

Tables 4-30 and 4-31 present data and calculations used to revise estimates of diesel exhaust emission factors presented in Biwer and Butler in Tables VI and VII. The revisions were made so that data used in analyses in the FEIS would reflect characteristics of the national truck fleet operational in 2010, the first year of proposed repository operations, and not in 1995, the year for data used in Biwer and Butler.

In Biwer and Butler (DIRS 151198-1999, Table VII), the diesel exhaust emission factor for 10 μm particles was 0.400 gram per kilogram. Based on the calculations presented in Table 4-30 and 4-31, the diesel exhaust emission factor for the fleet of Class VIIIB heavy trucks projected to be operational in 2010 was 0.141 gram per kilogram, about 65 percent less than the diesel exhaust emission factor used by Biwer and Butler.

Table 4-29. Calculation of fugitive dust emission factor for class VIIIB heavy trucks.

Vehicle Type	Annual VMT[a]	Weight[b] (tons)	Weight Times Annual VMT
Other[c]	6.82E+11	2.0	1.36E+12
LDV[d]	1.34E+12	2.0	2.68E+12
I	3.84E+11	3.0	1.15E+12
IIA	1.58E+11	4.3	6.81E+11
IIB	6.82E+10	5.0	3.41E+11
III	2.89E+09	9.8	2.83E+10
IV	1.92E+09	9.8	1.88E+10
V	1.04E+09	9.8	1.02E+10
VI	1.39E+10	16.5	2.30E+11
VII	2.85E+10	16.5	4.70E+11
VIIIA	1.23E+10	16.5	2.03E+11
VIIIB	7.65E+10	40.0	3.06E+12
Buses	2.71E+09		
Total[e]	2.77E+12		1.02E+13

a. Source: *Motor Vehicle-Related Air Toxics Study* (DIRS 155780-EPA 1993, p. G-19). VMT = vehicle miles traveled.

b. The weight for each vehicle class is taken from Biwer and Butler (DIRS 151198-1999, Table II).

c. Other VMT estimated by subtracting total truck VMT from nationwide vehicle fleet VMT. Other vehicles assumed to be light duty vehicles (LDVs).

d. LDV = light-duty vehicle

e. Nationwide fleet total VMT (2,771.30 x 10^9) taken from the *Motor Vehicle-Related Air Toxics Study* (DIRS 155780-EPA 1993, Table 9-3).

Notes:

1. Weighted average vehicle weight (W)= 3.69 tons.
2. Fugitive dust emissions based on average vehicle weight of 3.69 tons= 0.062 g/km for 2.5-μm particles. This value should be substituted for all values in Column 4 in Table VI of Biwer and Butler (DIRS 151198-1999).
3. Fugitive dust emissions based on average vehicle weight of 3.69 tons= 0.26 g/km for 10-μm particles. This value should be substituted for all values in Column 4 in Table VII of Biwer and Butler.

Table 4-30. Diesel particulate emissions in rural areas for fleet operational in 2010.

Year	VMT[a] (billion miles)	Diesel Mile Fraction[b]	Diesel Rural Fraction[c]	Rural Diesel Miles (billion miles)	Particulate Emission Rate[d] (g/mile)	Particulate Emissions[e] (billion g)
	Class VIIIB Diesel Trucks					
2010	10.707	1.0	0.74	7.923	0.217	1.722
2009	9.754	1.0	0.74	7.218	0.218	1.570
2008	8.825	1.0	0.74	6.531	0.218	1.426
2007	7.883	1.0	0.74	5.833	0.219	1.275
2006	6.939	1.0	0.74	5.135	0.219	1.126
2005	6.051	1.0	0.74	4.478	0.220	0.984
2004	5.165	1.0	0.74	3.822	0.220	0.843
2003	4.320	1.0	0.74	3.197	0.221	0.706
2002	3.551	1.0	0.74	2.628	0.221	0.581
2001	2.912	1.0	0.74	2.155	0.222	0.478
2000	2.358	1.0	0.74	1.745	0.222	0.388
1999	1.908	1.0	0.74	1.412	0.224	0.317
1998	1.517	1.0	0.74	1.123	0.227	0.255
1997	1.204	1.0	0.74	0.891	0.229	0.204
1996	0.942	1.0	0.74	0.697	0.232	0.162
1995	0.738	1.0	0.74	0.546	0.234	0.128
1994	0.587	1.0	0.74	0.434	0.236	0.103
1993	0.460	1.0	0.74	0.340	0.730	0.248
1992	0.359	1.0	0.74	0.265	0.736	0.195
1991	0.279	1.0	0.74	0.206	0.744	0.153
Total	76.459			56.580	0.227	12.863

a. Source: *Motor Vehicle-Related Air Toxics Study* (DIRS 155780-EPA 1993, p. G-19).
b. Source: *Motor Vehicle-Related Air Toxics Study* (DIRS 155780-EPA 1993. p. G-12).
c. Source: Rural fraction is 1-Urban Fraction, urban fraction found in, *Motor Vehicle-Related Air Toxics Study* (DIRS 155780-EPA 1993, p. G-20).
d. Source: *Motor Vehicle-Related Air Toxics Study* (DIRS 155780-EPA 1993, p. G-35).
e. Emission rate not adjusted for freeway use. See *Motor Vehicle-Related Air Toxics Study* (DIRS 155780-EPA 1993, p. 9-9).

Notes:

1. The emission rate for fleet in 2010 = 0.227 g/mile.
2. The emission rate for fleet in 2010 = 0.141 g/km.
3. The fleet emission rate of 0.141 g/km replaces value of 0.400 g/km in column 5 in Tables VI and VII of Biwer and Butler (DIRS 151198-1999) for Class VIIIB diesel trucks.

Table 4-31. Diesel particulate emissions in urban areas for fleet operational in 2010.

	Class VIIIB Diesel Trucks					
Year	VMT[a] (billion miles)	Diesel Mile Fraction[b]	Diesel Urban Fraction[c]	Rural Diesel Miles (billion miles)	Particulate Emission Rate[d] (g/mile)	Particulate Emissions[e] (billion g)
2010	10.707	1.0	0.26	2.784	0.217	0.605
2009	9.754	1.0	0.26	2.536	0.218	0.552
2008	8.825	1.0	0.26	2.295	0.218	0.501
2007	7.883	1.0	0.26	2.050	0.219	0.448
2006	6.939	1.0	0.26	1.804	0.219	0.395
2005	6.051	1.0	0.26	1.573	0.220	0.346
2004	5.165	1.0	0.26	1.343	0.220	0.296
2003	4.320	1.0	0.26	1.123	0.221	0.248
2002	3.551	1.0	0.26	0.923	0.221	0.204
2001	2.912	1.0	0.26	0.757	0.222	0.168
2000	2.358	1.0	0.26	0.613	0.222	0.136
1999	1.908	1.0	0.26	0.496	0.224	0.111
1998	1.517	1.0	0.26	0.394	0.227	0.089
1997	1.204	1.0	0.26	0.313	0.229	0.072
1996	0.942	1.0	0.26	0.245	0.232	0.057
1995	0.738	1.0	0.26	0.192	0.234	0.045
1994	0.587	1.0	0.26	0.153	0.236	0.036
1993	0.460	1.0	0.26	0.120	0.730	0.087
1992	0.359	1.0	0.26	0.093	0.736	0.069
1991	0.279	1.0	0.26	0.073	0.744	0.054
Total	76.459			19.879	0.227	4.520

a. Source: *Motor Vehicle-Related Air Toxics Study* (DIRS 155780-EPA 1993, p. G-19).
b. Source: *Motor Vehicle-Related Air Toxics Study* (DIRS 155780-EPA 1993, p. G-12).
c. Source: *Motor Vehicle-Related Air Toxics Study* (DIRS 155780-EPA 1993, p. G-20).
d. Source: *Motor Vehicle-Related Air Toxics Study* (DIRS 155780-EPA 1993, p. G-35).
e. Emission rate not adjusted for freeway use. See *Motor Vehicle-Related Air Toxics Study* (DIRS 155780-EPA 1993, p. 9-9).

Notes:

1. The emission rate for fleet in 2010 = 0.227 g/mile.
2. The emission rate for fleet in 2010 = 0.141 g/km.
3. The fleet emission rate of 0.141 g/km replaces value of 0.400 g/km in column 5 in Tables VI and VII of Biwer and Butler (DIRS 151198-1999) for Class VIIIB diesel trucks.

4.4.5.3 Age-Adjusted Baseline Mortality Rate

The PM_{10} risk factor used in Biwer and Butler (DIRS 151198-1999, all) was calculated using a baseline mortality rate of 0.008 (DIRS 152600-Ostro and Chestnut 1998, all). This rate appears to be a crude rate, which is influenced by age differences in population composition. In FEIS, an age-adjusted mortality rate of 0.005 (DIRS 103156-Bureau of the Census 1997, all) was used to calculate the PM_{10} risk factor. This eliminated the influences of age differences in the population composition.

4.4.5.4 Central Estimate Risk Factor

The PM_{10} risk factor used in Biwer and Butler (DIRS 151198-1999, all) was calculated using an upper-bound risk factor from Ostro and Chestnut (DIRS 152600-1998, all), who also presented a lower-bound estimate and a central estimate. The upper-bound risk estimate was based on a 3.5 percent change in mortality per 10 micrograms per cubic meter change in PM_{10} concentration. The lower-bound estimate was based on a 1.0 percent change in mortality per 10 micrograms per cubic meter change in PM_{10} concentration. The central estimate was the average of the upper and lower bounds, or a 2.3 percent change in mortality per 10 micrograms per cubic meter change in PM_{10} concentration.

The lifetime risk factor used in Biwer and Butler (DIRS 151198-1999) (0.0020 lifetime mortality per 1 micrograms per cubic meter change in PM_{10} concentration) was estimated using the equations:

Annual Risk Factor = Baseline Mortality Rate (crude) × Change Attributed to PM_{10}

Lifetime Risk Factor = Annual Risk Factor × 70 years

Annual Risk Factor = 0.008 deaths × 0.035 change in mortality per 10 μg per m^3 change in PM_{10} concentration = 2.8E-5 annual risk per 1 μg per m^3 change in PM_{10} concentration

Lifetime Risk Factor = 2.8E-5 annual risk × 70 years = 0.0020 lifetime risk per 1 μg per m^3 change in PM_{10} concentration

The lifetime risk factor used in the FEIS (0.00081 lifetime mortality per 1 μg per m^3 change in PM_{10} concentration) was estimated using the equations:

Annual Risk Factor = Baseline Mortality Rate (age adjusted) × Change Attributed to PM_{10}

Lifetime Risk Factor = Annual Risk Factor × 70 years

Annual Risk Factor = 0.005 deaths × 0.023 change in mortality per 10 μg per m^3 change in PM_{10} concentration = 1.2E-5 annual risk per 1 μg per m^3 change in PM_{10} concentration

Lifetime Risk Factor = 1.2E-5 annual risk × 70 years = 0.00081 lifetime risk per 1 μg per m^3 change in PM_{10} concentration.

4.4.5.5 Revised Unit Risk Factors For Estimating Impacts Of Vehicle Emissions

The unit risk factor for Class VIIIB trucks from Table VII of Biwer and Butler (DIRS 151198-1999, all) for 10-micrometer particles was 8.36E-10 fatalities per kilogram per person per square kilogram for an emission factor of 9.740 grams per kilogram and a PM-10 lifetime risk factor of 0.0020 lifetime risk per 1 microgram per cubic meter change in PM_{10} concentration.

For Class VIIIB trucks, the revised unit risk factor for 10-micrometer particles was 1.5E-11 fatalities per kilometer per person per square kilometer, based on an emission factor of 0.43 gram per kilometer and a PM_{10} lifetime risk factor of 0.00081 lifetime risk per 1 micrometers per cubic meter change in PM_{10} concentration:

8.36E-10 × 0.43 g/km ÷ 9.740 g/km × 8.1E-4 lifetime risk ÷ 0.0020 lifetime risk = 1.5E-11

For automobiles, the revised unit risk factor for 10 micrometers particles was 9.4E-12 fatalities per kilometer per person per square kilometer, based on an emission factor of 0.27 gram per kilometer and a PM_{10} lifetime risk factor of 0.00081 lifetime risk per 1 microgram per cubic meter change in PM_{10} concentration:

$$8.36E\text{-}10 \times 0.27 \text{ g/km} \div 9.740 \text{ g/km} \times 8.1E\text{-}4 \text{ lifetime risk} \div 0.0020 \text{ lifetime risk} = 9.4E\text{-}12$$

The unit risk factor for railcars from Table VII of Biwer and Butler (DIRS 151198-1999) for 10 micrometers particles was 1.2E-10 fatalities per kilometer per person per square kilometer for an emission factor of 1.41 gram per kilometer and a PM_{10} lifetime risk factor of 0.0020 lifetime risk per 1 microgram per cubic meter change in PM_{10} concentration.

The revised unit risk factor for railcars for 10 micrometers particles was 2.6E-11 fatalities per kilometer per person per square kilometers, based on an emission factor of 0.74 gram per kilogram and a PM_{10} lifetime risk factor of 0.00081 lifetime risk per 1 microgram per cubic meter change in PM_{10} concentration:

$$1.2E\text{-}10 \times 0.74 \text{ g/km} \div 1.41 \text{ g/km} \times 8.1E\text{-}4 \text{ lifetime risk} \div 0.0020 \text{ lifetime risk} = 2.6E\text{-}11$$

Table 4-32 summarizes the revised unit risk factors.

Table 4-32. Revised vehicle emission unit risk factors.

Vehicle Class	Weight (tons)	Tire/brake Particulates[a] (g/km)	Fugitive Dust[b] (g/km)	Diesel Exhaust[c] (g/km)	Total Emissions (g/km)	Unit Risk Factor (fatalities/km per person/km^2)
Automobiles[d]	2.0	0.013	0.26	0.0	0.27	9.4E-12
Class VIIIB Trucks	40	0.030	0.26	0.141	0.43	1.5E-11
Railcar	NA	NA	0.26	0.481	0.74	2.6E-11

a. Source: Table VII of Biwer and Butler (DIRS 151198-1999).
b. See Section 4.4.5.1.
c. See Section 4.4.5.2.
d. Automobile emissions estimated from data for light-duty diesel vehicles with diesel particulate emissions = 0 to account for use of gasoline engines in automobiles.

5.0 ACCIDENT ANALYSIS

5.1 Loadout and IMT Station Operations

5.1.1 INTRODUCTION

This section presents the impacts during loadout operations and IMT station operations due to accidents. The impacts include radiological accidents involving the mishandling or dropping of shipping casks, industrial safety impacts to loadout operations workers, industrial safety impacts to workers constructing an IMT station, industrial safety impacts to IMT operations workers, and traffic fatalities associated with the workers commuting to and from the work site during construction and operations.

5.1.2 METHODS

5.1.2.1 Loadout Operations

The analysis of radiological impacts due to accidents used existing information from several different sources (DIRS 104794-CRWMS M&O 1994, all; DIRS 103177 CP&L 1989, all; DIRS

103449-PGE 1996, all; DIRS 101816-DOE 1997, all;) to estimate potential radiological impacts from accidents involving the loading of SNF or HLW for shipment and handling of shipping casks. As summarized below, the results in these sources indicate that there would be no or negligible potential radiological consequences from accidents in all cases. Appendix J of the EIS describes typical operations for loading SNF in a shipping cask at a commercial facility.

The methodology for estimating industrial safety impacts to loadout operations workers is presented in Section 5.2.

In addition to radiological accidents, the number of traffic fatalities was estimated for loadout operations commuting workers.

5.1.2.2 IMT Station Operations

Shipping casks would arrive at an IMT station in Nevada by rail, and a gantry crane would transfer them from the railcars to heavy-haul trucks for transportation to the repository. The casks, which would not be opened or altered in any way at the IMT station, would be certified by the Nuclear Regulatory Commission and would be designed for accident conditions specified in 10 CFR Part 71. Impact limiters, which would protect casks against collisions during transportation, would remain in place during transfer operations at the IMT station.

DOE performed an accident screening process to identify credible accidents that could occur at an IMT station with the potential for compromising the integrity of the casks and releasing radioactive material. The external events listed in Table 5-1 were considered, along with an evaluation of their potential applicability.

As indicated from Table 5-1, the only accident-initiating event identified from among the feasible external events was the aircraft crash. Such events would be credible only for casks being handled or on transport vehicles at an IMT station in the Las Vegas area (Apex/Dry Lake or Sloan/Jean). For a station in the Las Vegas area, an aircraft crash would be from either commercial aircraft operations at McCarran International Airport or military operations from Nellis Air Force Base.

Among the internal events, the only potential accident identified was a drop of the cask during transfer operations. This accident would bound the other events considered, including drops from the railcar or truck (less fall height would be involved than during the transfer operations). Collisions, derailments, and other accidents involving the transport vehicles at the intermodal transfer would not damage the casks due to the requirement that they be able to withstand high-speed impacts and the low velocities of the transport vehicles at the IMT station.

Sabotage events were also considered as potential accident-initiating events at an IMT station. Section 5.3.4 evaluates such events.

Table 5-1. Screening analysis of external events considered potential accident initiators at IMT station. (1 of 2)

Event	Applicability
Aircraft crash	Retained for further evaluation
Avalanche	(a)
Coastal erosion	(a)
Dam failure	See flooding
Debris avalanching	(a)
Dissolution	(b)
Epeirogenic displacement (tilting of the earth's crust)	(c)
Erosion	(b)
Extreme wind	(c)
Extreme weather	(e)
Fire (range)	(b)
Flooding	(d)
Denudation	(b)
Fungus, bacteria, algae	(b)
Glacial erosion	(b)
High lake level	(b)
High tide	(a)
High river stage	See flooding
Hurricane	(a)
Inadvertent future intrusion	(b)
Industrial activity	Bounded by aircraft crash
Intentional future intrusion	(b)
Lightning	(c)
Loss of off/on-site power	(c)
Low lake level	(b)
Meteorite impact	(e)
Military activity	Retained for further evaluation
Orogenic diastrophism	(e)
Pipeline accident	(b)
Rainstorm	See flooding
Sandstorm	(c)
Sedimentation	(b)
Seiche	(a)
Seismic activity, uplifting	(c)
Seismic activity, earthquake	(c)
Seismic activity, surface fault	(c)
Seismic activity, subsurface fault	(c)
Static fracturing	(b)
Stream erosion	(b)
Subsidence	(c)
Tornado	(c)
Tsunami	(a)
Undetected past intrusions	(b)
Undetected geologic features	(b)
Undetected geologic processes	(c)

Table 5-1. Screening analysis of external events considered potential accident initiators at IMT station. (2 of 2)

Event	Applicability
Volcanic eruption	(e)
Volcanism, magmatic activity	(e)
Volcanism, ash flow	(c)
Volcanism, ash fall	(b)
Waves (aquatic)	(a)

a. Conditions at proposed sites do not allow event.
b. Not a potential accident initiator.
c. Bounded by cask drop accident considered in the internal events analysis.
d. Shipping cask designed for event.
e. Not credible, see evaluation for repository.

Accident Analysis

Cask Drop Accident:

The only internal event retained after the screening process was a failure of the gantry crane (due to mechanical failure or human error) during the transfer of a shipping cask from a railcar to a heavy-haul truck. The maximum height between the shipping cask and the ground during the transfer operation would be less than 6 meters (19 feet) (DIRS 104800-CRWMS M&O 1999, Heavy-Haul Files, Item 11). The casks would be designed to withstand a 9-meter (30-foot) drop. Therefore, the cask would be unlikely to fail during the event, especially because the impact energy from the 6-meter drop would be only 65 percent of the minimum design requirement.

Aircraft Crash Accident

Two of the three IMT station locations are near airports that handle large volumes of air traffic. The Apex/Dry Lake location is about 16 kilometers (10 miles) northeast of the Nellis Air Force Base runways. Between 60,000 and 67,000 takeoffs and landings occur at Nellis Air Force Base each year (DIRS 148083-Luedke 1997, all). The Sloan/Jean IMT area begins about 16 kilometers southwest of McCarran International Airport in Las Vegas. In 1996, McCarran had an average of 1,300 daily aircraft operations (DIRS 104725-Best 1998, all). Because of the large number of aircraft operations at these airports, the probability of an aircraft crash on the proposed IMT station could be within the credible range. To assess the consequences of an aircraft crash, an analysis evaluated the ability of large aircraft projectiles [jet engines and jet engine shafts (DIRS 101810-DOE 1996, p. 58) to penetrate the shipping casks. The analysis used a recommended formula (DIRS 101810 DOE 1996, p. 69) for predicting the penetration of steel targets, as follows:

$$T^{1.5} = 0.5 \times M \times V^2 \div 17{,}400 \times K_s \times D^{1.5}$$

where:

T = predicted thickness to just perforate a steel plate (inches)

M = projectile mass (weight/gravitational acceleration)

V = projectile impact velocity (feet per second)

K_s = constant depending on the grade of steel (usually about 1.0)

D = projectile diameter (inches)

The projectile characteristics listed in Table 5-2 are from Davis, Strenge, and Mishima (DIRS 103711-1998, all). The velocity used is about 130 meters (427 feet) per second, which is representative of aircraft velocities near airports (maximum velocity during takeoff and landing operations). A higher velocity [about 180 meters (590 feet) per second] was assumed for the projectile (commercial engine shaft) found to be limiting in terms of ability to penetrate to provide perspective on the influence of velocity on the penetration thickness. Table 5-3 lists the results of the penetration calculation.

The results indicate that none of the aircraft projectiles considered would penetrate the shipping casks, which would have metal shield walls about 18 centimeters (7 inches) thick (DIRS 101837-JAI 1996, all).

This evaluation found no credible accidents with the potential for radioactive release at an IMT station.

Table 5-2. Projectile characteristics.[a]

Aircraft	Engine weight (kilograms)[b]	Engine diameter (centimeters)[c]
Small military	420	71
Commercial	3,900	270

a. Source: Davis, Strenge, and Mishima (DIRS 103711-1998, Table 1).
b. To convert kilograms to pounds, multiply by 2.2046.
c. To convert centimeters to inches, multiply by 0.3937.

Table 5-3. Results of aircraft projectile penetration analysis.[a]

Projectile	Velocity (meters per second)[b]	Penetration thickness (centimeters)[c,d]
Small military engine	130	2.5
Small military shaft	130	2.5
Commercial engine	130	3.0
Commercial shaft	130	3.7
Commercial shaft	180	5.9

a. Source: Davis, Strenge, and Mishima (DIRS 103711-1998, Table 2).
b. To convert meters to feet, multiply by 3.2808.
c. To convert centimeters to inches, multiply by 0.3937.
d. Penetration through steel plate.

The methodology for estimating industrial safety impacts to IMT operations workers is presented in Section 5.2.

In addition to radiological accidents, the number of traffic fatalities was estimated for IMT commuting workers.

5.1.3 ASSUMPTIONS

5.1.3.1 Loadout Operations

- The radiological impacts due to loadout operations are comparable to operations at independent spent fuel storage installations.

- Based on DIRS 104794-CRWMS M&O(1994, all), there were no offsite impacts due to loadout operations.

- The assumptions for industrial safety operations are presented in Section 5.2.

- Traffic fatalities due to commuter travel for IMT workers are included with other potential traffic fatalities in the tables in Section 7.5.

- The examination of accidents during loadout operations at commercial nuclear power plant facilities was assumed to be applicable to DOE SNF handling facilities.

Table 5-4 presents the assumptions for loadout operations commuter traffic accident related impacts.

Table 5-4. Loadout commuter impacts - assumptions for traffic fatalities.

Assumption	Value	Reference
Round-trip kilometers	37	DOT-BTS[a]
Number of round trips per year	251	Number of workdays per year
Fatalities per kilometer	1.0E-08	BTS[b]

a. DIRS 150989-BTS 1998, all.
b. National average fatality rate for commuters from DIRS 148081-BTS 1999, all.

Lift-handling incidents involving SNF in a transfer facility would have an estimated probability of 0.0001 (1 in 10,000) per handling operation (DIRS 104794-CRWMS M&O 1994, pp. 3 to 8). The estimated collective dose to workers from the incidents would be no more than 0.1 person-rem, and it would be much less to the public.

5.1.3.2 IMT Station Operations

Table 5-5 presents assumptions for traffic-related accidents related to IMT station construction and operation.

Table 5-5. Commuter impacts – assumptions for traffic fatalities.

1.00E-08 Fatalities per kilometer for all commuters	
1.67E-08 Fatality rate for large trucks	
Round-trip distance (commuters and materials) (mi)	150
Round-trip distance (commuters and materials) (km)	241

5.1.4 USE OF COMPUTER SOFTWARE/MODELS

The industrial safety and traffic related fatalities to commuting workers were estimated using a personal computer running the Microsoft® Windows 2000 operating system and Microsoft® Excel® 2000.

5.1.5 CALCULATIONS/ANALYSIS AND RESULTS

5.1.5.1 Loadout Operations

The analysis of radiological impacts due to accidents during loadout operations used existing information from several different sources (DIRS 104794-CRWMS M&O 1994, all; DIRS

103177 CP&L 1989, all; DIRS 103449-PGE 1996, all; DIRS 101816-DOE 1997, all;) to estimate potential radiological impacts from accidents involving the loading of SNF or HLW for shipment and handling of shipping casks. One source (DIRS 104794-CRWMS M&O 1994, Sections 3.2 and 4.2) discusses potential accident scenario impacts of four cask management systems at electric utility and other SNF storage sites. This report concentrated on unplanned contact (bumping) during lift-handling of casks, canisters, or fuel assemblies. The two safety analysis reports for independent spent fuel storage installations for commercial SNF (DIRS 103449-PGE 1996, all; DIRS 103177-CP&L 1989, all) evaluated a comprehensive spectrum of accident-initiating events. These events included fires, chemical explosions, seismic events, nuclear criticality, tornado strikes and tornado-generated missile impacts, lightning strikes, volcanism, canister and basket drop, loaded shipping cask drop, and interference (bumping, binding) between the transfer cask and storage module. The DOE EISs for the interim management of SNF and HLW (DIRS 101802-DOE 1995, Appendix E; DIRS 101816-DOE 1997b, Appendixes F and G) included radiological impacts from potential accident scenarios associated with preparing, storing, and shipping these materials. These EISs do not discuss quantitative radiological impacts for accident scenarios associated with material loading, but do contain estimates of radiological impacts from accident scenarios for the SNF and HLW management activities considered. As discussed for routine loading operations, this analysis converted radiation doses to estimates of radiological impacts using dose-to-risk conversion factors of the International Commission on Radiological Protection.

The results in these sources indicate that there would be no or negligible potential radiological consequences from accidents in all cases. Section 4.1 of this document describes typical operations for loading SNF in a shipping cask at a commercial facility.

The methodology for estimating industrial safety impacts to loadout operations workers is presented in Section 5.2.

In addition to radiological accidents, the number of traffic fatalities was estimated for loadout operations commuting workers.

DOE expects the consequences of handling incidents that involved HLW would be less than those involving commercial SNF (DIRS 103237-CRWMS M&O 1998, p. 3). Thus, impacts from HLW handling would be less than the estimated 0.1 person-rem from a commercial SNF handling accident.

Reports on independent spent fuel storage installations and previous DOE analyses provide further evidence of the small probable impacts associated with a loading accident. Safety analysis reports prepared for independent spent fuel storage installations at the Trojan Nuclear Station and the Brunswick Steam Electric Plant concluded that there would be either no radiological consequences or very slight consequences from accidents that could occur at such facilities (DIRS 103449-PGE 1996, Section 8.2; DIRS 103177-CP&L 1989, Section 8.2). This analysis examined the potential magnitude of impacts from SNF storage facility operations. Only one event (loss of air outlet shielding blocks on a horizontal storage module, which a tornado projectile could cause) could result in a dose to an offsite member of the public. The estimated dose to an individual at a distance of 200 meters (656 feet) would be 0.0013 rem (a 7×10^{-7} probability—seven chances in 10 million—of an LCF) from direct and air-scattered (sky shine) radiation for a single horizontal storage module. The estimated dose to involved workers to recover from the event would be less than 0.09 person-rem (4×10^{-5} LCF). No other credible accidents involving a horizontal storage module had associated radiological consequences (DIRS 103437-NUTECH 1989, Section 10.2.3). Similarly, previous DOE analyses (DIRS 101816-DOE

1997, all; DIRS 104794 CRWMS M&O 1994, all) indicate that radiological consequences from accidents involving SNF and HLW management activities would be very small.

Table 5-6 summarizes the accident-related impacts from loadout operations. A folder titled "Loadout Operations," which contains the calculations of incident-free impacts, industrial safety impacts, and traffic fatality impacts due to loadout operations, is included separately on a compact disk. Table 5-7 lists the worksheets contained in the file titled "Loadout Impacts.xls" on the referenced compact disk.

5.1.5.2 IMT Station Operations

Table 5-8 presents the estimated traffic-related fatalities from IMT station construction and operations.

Table 5-6. Summary of nonradiological accident impacts from loadout operations.[a]

	Proposed Action		Module 1		Module 2	
Proposed Action	**Mostly LWT**	**Mostly Rail**	**Mostly LWT**	**Mostly Rail**	**Mostly LWT**	**Mostly Rail**
Total shipments[b]	52,786	9,646	105,685	18,243	108,791	18,935
FTEs[c]	3,456	1,518	6437.0	2612.8	6,649	2,703
TRCs[d]	132.2	58.0	246.2	99.9	254	103
LWCs[d]	72.0	25.8	122.7	44.4	126	46
Industrial safety fatalities	0.125	0.055	0.2	0.1	0.2410	0.0980
Total kilometers (commuting workers)[e]	40,122,775	17,617,188	63,944,220	25,743,435	66,403,632	27,768,335
Traffic fatalities	0.4	0.2	0.6	0.3	0.67	0.28

a. Industrial safety impacts presented in Section 5.2.
b. See Section 2.0.
c. Level of effort expressed as the number of FTE labor-hour multiples; one FTE is equivalent to 2,000 hours worked in an occupational year. Impacts among the noninvolved workforce would be about 25 percent of those shown.
d, TRC = total recordable (injury and illness) case; LWC = lost workday case.
e. Total kilometers based on total FTEs and a roundtrip distance of 37 kilometers (23 miles).

Table 5-7. Contents of "Loadout Impacts.xls."

Worksheet #	Description
1	Assumptions
2	Totals
3	Commercial SNF - Proposed Action
4	Commercial SNF - Modules 1 and 2
5	HLW - Proposed Action
6	HLW - Modules 1 and 2
7	DOE SNF - Proposed Action
8	DOE SNF - Module 1 and 2
9	GTCC waste
10	SPAR waste
11	Commercial SNF shipments
12	HLW shipments
13	DOE SNF shipments
14	Shipments summary

Table 5-8. Traffic fatality impacts from IMT construction and operations

IMT Station	Time	Number of Workers[a]	FTEs	One Round Trip	Total Kilometers	Traffic Fatalities
Construction	1.5	34	51	150	3,090,182	0.03
Operations	24	26	624	150	37,809,284	0.38
	38	26	988	150	59,864,700	0.60

a. Number of workers based on data presented in Section 8.0.

5.2 Industrial Safety Impacts

5.2.1 INTRODUCTION

This section presents the data and assumptions associated with estimating industrial safety impacts. The principal industrial safety impact parameters of importance to commercial industry and the Federal government are (1) total recordable (injury and illness) cases (TRCs), (2) lost workday cases (LWCs) associated with workplace injuries and illnesses, and (3) workplace fatalities. The frequency of these impacts under the Proposed Action and the inventory modules was projected using the involved worker level of effort, expressed as the number of FTE worker multiples, supporting shipment tasks. The representative workplace loss incidence rate for each impact parameter, as shown in the DOE Computerized Accident and Incident Reporting System (CAIRS) and Bureau of Labor Statistics database (DIRS 147938-DOE 1999, all) was obtained and used as a multiplier to convert the level of effort (FTEs) to expected industrial safety losses. All values are based on 1998 data, and the latest data published by the Bureau of Labor Statistics is 1998. In response, all data are representative of data from first quarter 1998 to fourth quarter 1998 (Bureau of Labor Statistics and CAIRS) for consistency of comparison.

DOE did not explicitly analyze impacts to noninvolved workers. For purposes of impact comparison in the Yucca Mountain EIS, DOE nonetheless assumed that there would be about one non-involved worker per four involved workers. This assumption is based on (1) DOE's experience with other projects that about one-fourth of workers would be assigned administrative or managerial duties, and (2) the fact that noninvolved worker loss incidence rates are generally no higher than those for involved workers.

The industrial safety impacts were estimated for the following labor groups:

1. Loadout operations workers at commercial and DOE generator sites
2. Rail corridor construction and operation workers
3. Heavy-haul route construction, operation, and upgrade workers
4. IMT station construction and operation workers

The number of workers or FTEs for each category were estimated and multiplied by the industrial safety impacts factors to determine total impacts for an activity. The method used to derive the number of FTEs for each activity is discussed in Section 5.2.2.

5.2.2 METHOD

This section presents the number of FTEs for each activity and the industrial safety impact factors for those activities.

5.2.2.1 Loadout Operations

The involved worker FTE multiples assigned to each shipment option and fuel type (PWR or BWR) was estimated using the following formula:

$$\text{Involved Worker FTE Multiples} \equiv (A \times B \times C \times D) \div E$$

where:

A = number of PWR or BWR SNF shipments being analyzed under each transportation option (see shipments calculation package or Appendix J of the Yucca Mountain EIS)

B = average loading duration for each shipment, by fuel type and conveyance mode (workdays; from Table 4-1 of this calculation package)

C = workday conversion factor (≡ 8 hours per workday)

D = involved worker crew size (13 workers; from Table 4-2 of this calculation package)

E = FTE conversion factor = 2,000 worker-hours per FTE

The representative Bureau of Labor statistics database loss incidence rates for each TRC, LWC, and fatality trauma category (e.g., number of TRCs per FTE) were computed using worker FTE multiples to project the associated trauma incidence.

5.2.2.2 Rail Corridor, Heavy-haul Route, and IMT Station Construction and Operation

The Environmental Baseline File for Transportation (DIRS 104800-CRWMS M&O 1999, all) contains the estimate of worker data for the construction and operation of a branch rail line, upgrade, operation, and resurface of the heavy-haul routes and the construction and operation of an IMT station.

5.2.2.3 Industrial Safety Impacts from Loadout Operations

The involved worker Bureau of Labor Statistics TRC incidence rate, 145,700 TRCs in a workforce of 1,739,000 workers (0.084 TRC/FTE), reflects losses in the Trucking and Warehousing sector during the 1998 period of record. The same Bureau of Labor Statistics period of record and industry sector was used to select the involved worker LWC incidence rate (80,800 LWCs in a workforce of 1,739,000 workers [0.046 lost workday/FTE]). The involved worker fatality incidence rate, 23.4 fatalities in a workforce of 100,000 workers, reflects losses in the Transportation and Material Moving Occupations sector during the Bureau of Labor Statistics 1998 period of record.

The noninvolved worker TRC incidence rate, 61,000 TRCs in a workforce of 3,170,300 workers, reflects losses in the Engineering and Management Services sector during the Bureau of Labor Statistics 1998 period of record. The same Bureau of Labor Statistics period of record and industry sector was used to select the noninvolved worker LWC incidence rate (22,400 LWCs in a workforce of 3,170,300 workers [0.0071 lost workday/FTE]). The noninvolved worker fatality incidence rate, 1.6 fatalities in a workforce of 100,000 workers, reflects losses in the Managerial and Professional Specialties sector during the Bureau of Labor Statistics 1998 period of record.

The technical approach and loss multipliers used to estimate industrial safety impacts for loading operations at commercial generator sites were also used to estimate industrial safety impacts of loading and shipping SNF and HLW loading impacts at DOE sites.

5.2.2.4 Rail Corridor Construction

The involved worker Bureau of Labor Statistics TRC incidence rate, 65,200 TRCs in a workforce of 827,900 workers (0.079 TRCs/FTE), reflects losses in the Heavy Construction sector, except for the Building Contractors sector during the Bureau of Labor Statistics 1998 period of record. The same Bureau of Labor Statistics period of record and industry sector was used to select the involved worker LWC incidence rate (32,500 LWCs in a workforce of 827,900 workers [0.039 lost workday/FTE]). The involved worker fatality incidence rate, 11.2 fatalities in a workforce of 100,000 workers (0.00011 fatalities/FTE) reflects losses in the Total Construction (except Supervisors) sector during the Bureau of Labor Statistics 1998 period of record. This incidence rate was selected because no fatality incidence data were available for the Heavy Construction sector, although the Building Contractors sector and rail corridor station construction would employ personnel from the commercial construction profession.

The noninvolved worker TRC incidence rate, 61,000 TRCs in a workforce of 3,170,300 workers (0.019 TRCs/FTE), reflects losses in the Engineering Management Services sector during the Bureau of Labor Statistics 1998 period of record. The same Bureau of Labor Statistics period of record and industry sector was used to select the noninvolved worker LWC incidence rate (22,400 LWCs in a workforce of 3,170,300 workers [0.0071 lost workdays/FTE]). The noninvolved worker fatality incidence rate, 1.6 fatalities in a workforce of 100,000 workers (0.00002 fatalities/FTE), reflects losses in the Managerial and Professional Specialty Occupations sector during the Bureau of Labor Statistics 1998 period of record. This incidence rate was selected because no fatality incidence data were available for the Engineering Management Services sector and Rail Corridor station construction would employ engineering and management support personnel as noninvolved workers.

5.2.2.5 Heavy-Haul Construction

The involved worker Bureau of Labor Statistics TRCs incidence rate, 65,200 TRCs in a workforce of 827,900 workers (0.079 TRC/FTE), reflects losses in the Heavy Construction-Except Building Contractors sector during the Bureau of Labor Statistics 1998 period of record. The same Bureau of Labor Statistics period of record and industry sector was used to select the involved worker LWC incidence rate (32,500 LWCs in a workforce of 827,900 workers [0.039 lost workdays/FTE]). The involved worker fatality incidence rate, 11.2 fatalities in a workforce of 100,000 workers (0.00011 fatalities/FTE), reflects losses in the Total Construction sector during the Bureau of Labor Statistics 1998 period of record. This incidence rate was selected because no fatality incidence data were available for the Heavy Construction sector, although the Building Contractors sector and Rail Corridor station construction would employ personnel from the commercial construction profession.

The noninvolved worker TRC incidence rate, 61,000 TRCs in a workforce of 3,170,300 workers (0.019 TRCs/FTE), reflects losses in the Engineering Management Services sector during the Bureau of Labor Statistics 1998 period of record. The same Bureau of Labor Statistics period of record and industry sector was used to select the noninvolved worker LWC incidence rate (22,400 LWCs in a workforce of 3,170,300 workers [0.0071 LWD/FTE]). The noninvolved worker fatality incidence rate, 1.6 fatalities in a workforce of 100,000 workers (0.00002 fatalities/FTE), reflects losses in the Managerial and Professional Specialty Occupations sector during the Bureau of Labor Statistics 1998 period of record. This incidence rate was selected because no fatality incidence data were available for the Engineering Management Services sector and Rail Corridor station construction would employ engineering and management support personnel as noninvolved workers.

Note: The data in this section mirror the Rail Corridor data because there are no data specific to Rail Corridor and Heavy-Haul construction. Bureau of Labor Statistics data for these items are grouped into the general Heavy Construction-Except Building sector.

5.2.2.6 IMT Station Industrial Safety Impacts from Construction

The involved worker Bureau of Labor Statistics TRC incidence rate, 103,200 TRCs in a workforce of 1,370,600 workers (0.075 TRC/FTE), reflects losses in the General Building Contractors sector during the Bureau of Labor Statistics 1998 period of record. The same Bureau of Labor Statistics period of record and industry sector was used to select the involved worker LWC incidence rate (47,500 LWCs in a workforce of 1,370,600 workers [0.035 lost workdays/FTE]). The involved worker fatality incidence rate, 11.2 fatalities in a workforce of 100,000 workers (0.00011 fatalities/FTE), reflects losses in the Construction Trades sector during the Bureau of Labor Statistics 1998 period of record. This incidence rate was selected because no fatality incidence data were available for the General Building Contractors sector and IMT station construction would employ personnel from the commercial construction profession.

The noninvolved worker TRC incidence rate, 191,200 TRCs in a workforce of 8,590,900 workers (0.022 TRC/FTE), reflects losses in the Business Services sector during the Bureau of Labor Statistics 1998 period of record. The same Bureau of Labor Statistics period of record and industry sector was used to select the noninvolved worker LWC incidence rate (87,500 LWCs in a workforce of 8,590,900 workers [0.01 lost workdays/FTE]). The noninvolved worker fatality incidence rate, 0.6 fatalities in a workforce of 100,000 workers (0.00001 fatalities/FTE), reflects losses in the Administrative Support Jobs (Including Clerical) sector during the Bureau of Labor Statistics 1998 period of record. This incidence rate was selected because no fatality incidence data were available for the Business Services sector and IMT station construction would employ administrative support personnel as noninvolved workers.

5.2.2.7 IMT Station - Industrial Safety Impacts from Operations

The representative workplace loss incidence rate for each impact parameter (as compiled by the Bureau of Labor Statistics) was obtained and used as a multiplier to convert the operations crew level of effort (16 FTEs per year) to expected industrial safety losses. The involved worker FTE multiples that would be assigned to operate the IMT station were taken from the Nevada transportation engineering files (DIRS 155347-CRWMS M&O). Noninvolved worker FTE multiples were unavailable, so DOE assumed that the noninvolved worker level of effort would be about 25 percent of that for the involved workers (i.e., four FTEs per year). The Bureau of Labor Statistics loss incidence rate for each TRC, LWCs, and fatality trauma category (e.g., number of TRCs per FTE) was then multiplied by the involved and noninvolved worker FTE multiples to project the associated trauma incidence.

The involved worker Bureau of Labor Statistics TRC incidence rate, 145,700 TRCs in a workforce of 1,739,000 workers (0.084 TRC/FTE), reflects losses in the Trucking and Warehousing sector during the 1998 period of record. The same Bureau of Labor Statistics period of record and industry sector was used to select the involved worker LWC incidence rate (80,800 LWCs in a workforce of 1,739,000 workers [0.046 lost workdays/FTE]). The involved worker fatality incidence rate, 23.4 fatalities in a workforce of 100,000 workers, reflects losses in the Transportation and Material Moving Occupations sector during the Bureau of Labor Statistics 1998 period of record.

The noninvolved worker TRC incidence rate, 61,000 TRCs in a workforce of 3,170,300 workers reflects losses in the Engineering and Management Services sector during the Bureau of Labor Statistics 1998 period of record. The same Bureau of Labor Statistics period of record and industry sector was used to select the noninvolved worker LWC incidence rate (22,400 LWCs in a workforce of 3,170,300 workers (0.0071 lost workdays/FTE]). The noninvolved worker fatality incidence rate, 1.6 fatalities in a workforce of 100,000 workers, reflects losses in the Managerial and Professional Specialties sector during the Bureau of Labor Statistics 1998 period of record.

5.2.3 ASSUMPTIONS

The following assumptions were used to estimate industrial safety impacts for the Yucca Mountain FEIS:

- The analysis assumed that one non-involved worker for every four involved workers represented impacts to noninvolved workers. This assumption is based on (1) DOE's experience with other projects on the number of workers would be assigned administrative or managerial duties, and (2) the fact that noninvolved worker loss incidence rates are generally no higher than those for involved workers.
- FTE conversion factor (= 2,000 worker-hours per FTE)
- IMT station construction and operation workers - The number of workers or FTEs for each category was estimated and multiplied by the industrial safety impacts factors to determine total impacts for an activity. The method used to derive the number of FTEs for each activity is discussed in Section 5.2.2.
- Other assumptions regarding industrial safety factors are presented in Section 5.2.2
- The industrial sector loss indicators would apply to DOE and nuclear industry activities.

5.2.4 USE OF COMPUTER SOFTWARE/MODELS

The industrial safety impact factors were obtained from the Bureau of Labor Statistics database. The impact factors (TRCs, LWCs, and fatalities) were used in a Microsoft® Excel spreadsheet combined with estimates of worker FTEs to determine total impacts for each category.

5.2.5 CALCULATION/ANALYSIS AND RESULTS

This section presents the data and assumptions used to estimate industrial safety impacts for at-reactor loadout operations, rail corridor construction, heavy-haul route construction, IMT station construction, and IMT operations. The industrial safety impacts for both involved and noninvolved workers are presented in terms of the following impact categories:

- Total recordable (injury and illness) cases
- LWCs
- Fatalities

Table 5-9 summarizes the data presented in this section. Table 5-10 lists the references for the data used to complete Table 5-9.

The industrial safety impacts for each of the work forces analyzed are presented on the Microsoft® Excel spreadsheets in the Industrial Safety Impacts FEIS folder on compact disk. Table 5-11 lists the content for each of the industrial safety worksheets presented.

Table 5-9. Industrial safety impact factors (based on 1998 data).

Category	Loadout Operations	Rail Corridor Construction	Heavy-Haul Construction	IMT[d] Construction	IMT Operations
Involved Worker					
TRC[a]	0.084	0.079	0.079	0.075	0.084
LWCs[b]	0.046	0.039	0.039	0.035	0.046
Fatalities	0.00023	0.00011	0.00011	0.00011	0.00023
Noninvolved Workers[c]					
TRC[a]	0.019	0.019	0.019	0.022	0.019
LWCs[b]	0.0071	0.0071	0.0071	0.01	0.0071
Fatalities	0.00002	0.00002	0.00002	0.00001	0.00002

a. TRC = total recordable case.
b. LWC = lost workday case.
c. The noninvolved worker impacts are based on 25 percent of the involved worker level of effort.
d, IMT – intermodal transfer.

Table 5-10. References for Table 5-9. (1 of 4)

	Involved Worker	Noninvolved Worker
Loadout operations – TRCs	See IMT Operations	See IMT Operations
Loadout operations – LWCs	See IMT Operations	See IMT Operations
Loadout operations - fatalities	See IMT Operations	See IMT Operations
Rail corridor - TRCs	DIRS 157337 – BLS (Bureau of Labor Statistics) 2001, "Table 1. Incidence Rates of Nonfatal Occupational Injuries and Illnesses, by Industry and Selected Case Types, 1998," "Heavy Construction-Except Building" http://stats.bls.gov/ iif/oshwc/osh/os/osnr0009.txt Bureau of Labor Statistics, Washington, D.C. NOTE: The URL cited in the above reference is linked to a dynamic database.	DIRS 157337 – BLS (Bureau of Labor Statistics) 2001, "Table 1. Incidence Rates of Nonfatal Occupational Injuries and Illnesses, by Industry and Selected Case Types, 1998," "Engineering Management Services" http://stats.bls.gov/ iif/oshwc/osh/os/osnr0009.txt, Bureau of Labor Statistics, Washington, D.C. NOTE: The URL cited in the above reference is linked to a dynamic database.
Rail corridor – LWCs	DIRS 157337 – BLS (Bureau of Labor Statistics) 2001, "Table 1. Incidence Rates of Nonfatal Occupational Injuries and Illnesses, by Industry and Selected Case Types, 1998," "Heavy Construction, except Building" http://stats.bls.gov/ iif/oshwc/osh/os/osnr0009.txt Bureau of Labor Statistics, Washington, D.C. NOTE: The URL cited in the above reference is linked to a dynamic database.	DIRS 157336 – BLS (Bureau of Labor Statistics) 2001, "Nonfatal Occupational Injury and Illness Incidence Rates of Total Recordable Cases by Quartile Distribution and Employment Size Group, Private Industry, 1998," "Engineering and Management Services" http://stats.bls.gov/ iif/oshwc/osh/os/ostb0770.txt, Bureau of Labor Statistics, Washington, D.C. NOTE: The URL cited in the above reference is linked to a dynamic database.
Rail corridor - fatalities	DIRS 157334 – BLS (Bureau of Labor Statistics) 2001, "Table A-1. Fatal Occupational Injuries by Industry and Event or Exposure, 1998," "Total Construction" hhttp://stats.bls.gov/iif/oshwc/cfoi/cftb0112.txt (Specific Contact Dave Schmidt, U.S. Department of Labor Occupational Safety and Health Administration, Office of Statistics), and Bureau of Labor Statistics, Washington, D.C. "Total Construction" was used because the Bureau of Labor Statistics did not have specific rates for "Heavy Construction-except Building." NOTE: The URL cited in the above reference is linked to a dynamic database.	DIRS 157334 – BLS (Bureau of Labor Statistics) 2001, "Table A-1. Fatal Occupational Injuries by Industry and Event or Exposure, 1998," "Managerial and Professional Specialty Occupations" http://stats.bls.gov/iif/oshwc/cfoi/cftb0112.txt (Specific Contact Dave Schmidt , U.S. Department of Labor Occupational Safety and Health Administration, Office of Statistics), and Bureau of Labor Statistics, Washington, D.C. "Managerial and Professional Specialty Occupations" was used because the Bureau of Labor Statistics did not have specific rates for "Engineering and Management Services." NOTE: The URL cited in the above reference is linked to a dynamic database.

Table 5-10. References for Table 5-9. (2 of 4)

	Involved Worker	Noninvolved Worker
Heavy-haul construction - TRCs	DIRS 157336 – BLS (Bureau of Labor Statistics) 2001, "Nonfatal Occupational Injury and Illness Incidence Rates of Total Recordable Cases by Quartile Distribution and Employment Size Group, Private Industry, 1998," "Heavy Construction-Except Building" http://stats.bls.gov/iif/oshwc/osh/os/ostb0770.txt, Bureau of Labor Statistics, Washington, D.C. NOTE: The URL cited in the above reference is linked to a dynamic database.	DIRS 157336 – BLS (Bureau of Labor Statistics) 2001, "Nonfatal Occupational Injury and Illness Incidence Rates of Total Recordable Cases by Quartile Distribution and Employment Size Group, Private Industry, 1998," "Engineering Management Services" http://stats.bls.gov/iif/oshwc/osh/os/ostb0770.txt, Bureau of Labor Statistics, Washington, D.C. NOTE: The URL cited in the above reference is linked to a dynamic database.
Heavy-haul construction – LWCs	DIRS 157336 – BLS (Bureau of Labor Statistics) 2001, "Nonfatal Occupational Injury and Illness Incidence Rates of Total Recordable Cases by Quartile Distribution and Employment Size Group, Private Industry, 1998," "Heavy Construction, Except Building" http://stats.bls.gov/iif/oshwc/osh/os/ostb0770.txt Bureau of Labor Statistics, Washington, D.C. NOTE: The URL cited in the above reference is linked to a dynamic database.	DIRS 157336 – BLS (Bureau of Labor Statistics) 2001, "Nonfatal Occupational Injury and Illness Incidence Rates of Total Recordable Cases by Quartile Distribution and Employment Size Group, Private Industry, 1998," "Engineering and Management Services" http://stats.bls.gov/iif/oshwc/osh/os/ostb0770.txt, Bureau of Labor Statistics, Washington, D.C. NOTE: The URL cited in the above reference is linked to a dynamic database.
Heavy-haul construction - fatalities	DIRS 157334 – BLS (Bureau of Labor Statistics) 2001, "Table A-1. Fatal Occupational Injuries by Industry and Event or Exposure, 1998," "Total Construction" http://stats.bls.gov/iif/oshwc/cfoi/cftb0112.txt (Specific Contact Dave Schmidt, U.S. Department of Labor Occupational Safety and Health Administration, Office of Statistics), and Bureau of Labor Statistics, Washington, D.C.	DIRS 157334 – BLS (Bureau of Labor Statistics) 2001, "Table A-1. Fatal Occupational Injuries by Industry and Event or Exposure, 1998," "Managerial and Professional Specialty Occupations" http://stats.bls.gov/iif/oshwc/cfoi/cftb0112.txt (Specific Contact Dave Schmidt, U.S. Department of Labor Occupational Safety and Health Administration, Office of Statistics), and Bureau of Labor Statistics, Washington, D.C.
Heavy-haul construction – fatalities (cont'd)	"Total Construction" was used because the Bureau of Labor Statistics did not have specific rates for "Heavy Construction-except Building." NOTE: The URL cited in the above reference is linked to a dynamic database.	"Managerial and Professional Specialty Occupations" was used because the Bureau of Labor Statistics did not have specific rates for "Engineering and Management Services." NOTE: The URL cited in the above reference is linked to a dynamic database.

Table 5-10 References for Table 5-9. (3 of 4)

	Involved Worker	Noninvolved Worker
IMT station construction - TRCs	DIRS 157336 – BLS (Bureau of Labor Statistics) 2001, "Nonfatal Occupational Injury and Illness Incidence Rates of Total Recordable Cases by Quartile Distribution and Employment Size Group, Private Industry, 1998," "General Building Contractors" http://stats.bls.gov/ iif/oshwc/osh/os/ostb0770.txt Bureau of Labor Statistics, Washington, D.C. NOTE: The URL cited in the above reference is linked to a dynamic database.	DIRS 157336 – BLS (Bureau of Labor Statistics) 2001, "Nonfatal Occupational Injury and Illness Incidence Rates of Total Recordable Cases by Quartile Distribution and Employment Size Group, Private Industry, 1998," "Business Services" http://stats.bls.gov/ iif/oshwc/osh/os/ostb0770.txt Bureau of Labor Statistics, Washington, D.C. NOTE: The URL cited in the above reference is linked to a dynamic database.
IMT station construction – LWCs	DIRS 157336 – BLS (Bureau of Labor Statistics) 2001, "Nonfatal Occupational Injury and Illness Incidence Rates of Total Recordable Cases by Quartile Distribution and Employment Size Group, Private Industry, 1998," "General Building Contractors" http://stats.bls.gov/ iif/oshwc/osh/os/ostb0770.txt Bureau of Labor Statistics, Washington, D.C. NOTE: The URL cited in the above reference is linked to a dynamic database.	DIRS 157336 – BLS (Bureau of Labor Statistics) 2001, "Nonfatal Occupational Injury and Illness Incidence Rates of Total Recordable Cases by Quartile Distribution and Employment Size Group, Private Industry, 1998," "Business Services" http://stats.bls.gov/ iif/oshwc/osh/os/ostb0770.txt Bureau of Labor Statistics, Washington, D.C. NOTE: The URL cited in the above reference is linked to a dynamic database.
IMT station construction - fatalities	DIRS 157334 – BLS (Bureau of Labor Statistics) 2001, "Table A-1. Fatal Occupational Injuries by Industry and Event or Exposure, 1998," "Construction Trades" http://www.bls.gov/news.release/cfoi.t02.htm, Bureau of Labor Statistics, Washington, D.C. NOTE: The URLs cited in the above references are linked to dynamic databases.	DIRS 157334 – BLS (Bureau of Labor Statistics) 2001, "Table A-1. Fatal Occupational Injuries by Industry and Event or Exposure, 1998," "Administrative Support Occupations, including Clerical" http://www.bls.gov/news.release/cfoi.t02.htm, Bureau of Labor Statistics, Washington, D.C. DIRS 157335 – BLS (Bureau of Labor Statistics) 2001, "Occupational Employment and Wages, 1998" "Administrative Support Occupations, including Clerical" http://www.bls.gov/pdf/cpsaat10.pdf NOTE: The URLs cited in the above references are linked to dynamic databases.

Table 5-10. References for Table 5-9. (4 of 4)

	Involved Worker	Noninvolved Worker
IMT station and Loadout operations - TRCs	DIRS 157336 – BLS (Bureau of Labor Statistics) 2001, "Nonfatal Occupational Injury and Illness Incidence Rates of Total Recordable Cases by Quartile Distribution and Employment Size Group, Private Industry, 1998," "Trucking and Warehousing" http://stats.bls.gov/news.release/osh.t02.htm, Bureau of Labor Statistics, Washington, D.C. NOTE: The URL cited in the above reference is linked to a dynamic database.	DIRS 157336 – BLS (Bureau of Labor Statistics) 2001, "Nonfatal Occupational Injury and Illness Incidence Rates of Total Recordable Cases by Quartile Distribution and Employment Size Group, Private Industry, 1998," "Engineering and Management Services" http://stats.bls.gov/news.release/osh.t02.htm, Bureau of Labor Statistics, Washington, D.C. Data for the "Engineering and Management Services" industry was selected for the TRC rate. NOTE: The URL cited in the above reference is linked to a dynamic database.
IMT station and loadout operations – LWCs	DIRS 157336 – BLS (Bureau of Labor Statistics) 2001, "Nonfatal Occupational Injury and Illness Incidence Rates of Total Recordable Cases by Quartile Distribution and Employment Size Group, Private Industry, 1998," "Trucking and Warehousing" http://stats.bls.gov/news.release/osh.t02.htm, Bureau of Labor Statistics, Washington, D.C. NOTE: The URL cited in the above reference is linked to a dynamic database.	DIRS 157336 – BLS (Bureau of Labor Statistics) 2001, "Nonfatal Occupational Injury and Illness Incidence Rates of Total Recordable Cases by Quartile Distribution and Employment Size Group, Private Industry, 1998," "Engineering and Management Services" http://stats.bls.gov/news.release/osh.t02.htm, Bureau of Labor Statistics, Washington, D.C. NOTE: The URL cited in the above reference is linked to a dynamic database.
IMT station and loadout operations - fatalities	DIRS 157334 – BLS (Bureau of Labor Statistics) 2001, "Table A-1. Fatal Occupational Injuries by Industry and Event or Exposure, 1998," "Transportation and Material Moving Occupations" http://www.bls.gov/news.release/cfoi.t02.htm, Bureau of Labor Statistics, Washington, D.C. DIRS 157335 – BLS (Bureau of Labor Statistics) 2001, "Occupational Employment and Wages, 1998" "Transportation and Material Moving Occupations" http://www.bls.gov/pdf/cpsaat10.pdf NOTE: The URLs cited in the above references are linked to dynamic databases.	DIRS 157334 – BLS (Bureau of Labor Statistics) 2001, "Table A-1. Fatal Occupational Injuries by Industry and Event or Exposure, 1998," "Managerial and Professional Specialties" http://stats.bls.gov/special.requests/ocwc/oshwc/cfoi/cfnr0005.pdf Bureau of Labor Statistics, Washington, D.C. DIRS 157335 – BLS (Bureau of Labor Statistics) 2001, "Occupational Employment and Wages, 1998" "Managerial and Professional Specialties" http://www.bls.gov/pdf/cpsaat10.pdf, Bureau of Labor Statistics, Washington, D.C. NOTE: The URLs cited in the above references are linked to dynamic databases.

Table 5-11. Summary of industrial safety data and impacts in attached spreadsheets.

Spreadsheet #	Summary of data and analysis on spreadsheet
1	The first spreadsheet presents factors used to estimate incidences of industrial safety impacts. Data are presented for involved and noninvolved workers for total recordable industrial safety cases, LWCs, and fatalities. Sources for each data entry are cited on the seven pages that follow the spreadsheet.
2	This spreadsheet presents data used and results of calculations of impacts for construction and operations of an IMT station. The spreadsheet presents results for impacts under the Proposed Action and Modules 1 and 2. Impacts were calculated using incidence rates listed on Spreadsheet #1.
3	This spreadsheet presents data used and results of calculations of impacts for construction and operations of a branch rail line in Nevada. The spreadsheet presents results for impacts under the Proposed Action. Impacts were calculated using incidence rates listed on Spreadsheet #1. Impacts are presented for each potential rail corridor in Nevada.
4	This spreadsheet presents data used and results of calculations of impacts for construction and operations of a branch rail line in Nevada. The spreadsheet presents results for impacts under Modules 1 and 2. Impacts were calculated using incidence rates listed on Spreadsheet #1. Impacts are presented for each potential rail corridor in Nevada.
5	This spreadsheet presents incidence rates, construction time, and employment data used to estimate industrial safety impacts for upgrading and maintaining highways for, and operating, heavy-haul trucks in Nevada. Operations employment (FTEs) data are for the Proposed Action.
6	This spreadsheet presents the evaluated industrial safety impacts of highway upgrades for, and operations involving, heavy-haul trucks in Nevada for the Proposed Action. The data are presented for each of the five potential routes listed in the EIS. Operations impacts on this spreadsheet include impacts of annual maintenance of the affected highways and major resurfacing every 8 years.
7	This spreadsheet presents the evaluated industrial safety impacts of highway upgrades for, and operations involving, heavy-haul trucks in Nevada for Modules 1 and 2. The data are presented for each of the five potential routes listed in the EIS. Operations impacts on this spreadsheet include impacts of annual maintenance of the affected highways and major resurfacing every 8 years.
8	This spreadsheet presents incidence rates, construction time, and employment data used to estimate industrial safety impacts for upgrading and maintaining highways for, and operating, heavy-haul trucks in Nevada. Operations employment (FTEs) data include data for the Proposed Action and for Modules 1 and 2.
9	This spreadsheet presents data and results used to estimate industrial safety impacts of IMT operations for naval SNF shipment under the mostly legal-weight truck scenario. For this scenario, the analysis assumed shipments of naval SNF would use commercial IMT services. The analysis assumed an IMT station would not be constructed for 300 navy cask-railcar shipments over 24 years.
10	This spreadsheet presents data and results for analyzing impacts of IMT operations for shipments from 19 commercial generator sites not served by a railroad. For the mostly rail scenario, the analysis assumed these 19 sites, which could handle and load a rail-size transportation cask, would ship by heavy-haul truck or barge to a nearby IMT facility, where casks would be transferred from trucks (or barges) to railcars.

5.3 Radiological Accident Dose Risk

5.3.1 NONRADIOLOGICAL TRANSPORTATION ACCIDENTS

5.3.1.1 Introduction

This section considers nonradiological transportation impacts related to the transportation of SNF and HLW to the proposed repository. The nonradiological transportation impact measure considered is traffic fatalities. In addition to considering the potential for traffic fatalities during the transportation of HLW to the proposed repository, the analysis also considers the potential for traffic fatalities involving escort vehicle travel and worker commuting.

5.3.1.2 Methods

Truck, rail, and barge traffic fatality rates were obtained from DIRS 103455-Saricks and Tompkins (1999) (Table 4 for trucks and Table 6 for freight rail). In Table 4, the state-specific fatality rate for interstate heavy combination (semi-detached) trucks traveling on interstate highways was used for legal-weight truck transport of SNF and HLW, and the state-specific primary road fatality rate was used for heavy-haul truck transport of these materials. The rail transport analysis also used state-specific fatal accident rates. However, the barge analysis used the national average barge fatal accident rate. All data were taken directly from the tables in the Saricks and Tompkins report. Automobile traffic fatality rates were used to estimate the number of escort and commuter fatalities. These rates were obtained from DIRS 148080-Bureau of Transportation Statistics, 1996, all.

These data (DIRS 103455-Saricks and Tompkins 1999, Tables 4 and 6) were used to estimate the total number of fatalities that might occur for the Mostly Truck, Mostly Rail, and Barge cases for the Proposed Action, Module 1, and Module 2. The database described in Appendix A provides distances in each state for each of the cases and module alternatives being considered. Impacts (potential traffic fatalities) were calculated by multiplying the distance traveled by the state- and mode-specific fatal accident rates to obtain an estimate of the total number of fatalities that might occur for each case and module.

For commuting workers, impacts were estimated using the average round-trip commuting distance of 241 kilometers (150 miles) (DIRS 152985-DOE 2000, Section 3.1.2) and multiplying by the automobile traffic fatality rate. The estimated numbers of traffic fatalities associated with the transport of materials and commuter travel to the proposed repository site are presented in Section 6.0. The estimated numbers of traffic fatalities associated with the transport of SNF and HLW, including escort traffic fatalities, are presented in Section 7.5.

5.3.1.3 Assumptions

The assumptions made in calculating potential traffic fatalities are:

- The total kilometers of travel used in the incident-free and accident risk calculations for each alternative being considered are multiplied by a factor of two to estimate the number of traffic fatalities. Thus, the fatalities associated with the transport of empty casks from the repository to the location where the SNF and HLW are located are also considered in the analysis.

- For the Proposed Action base case for legal-weight truck transportation, in the mostly truck, mostly rail, and barge scenarios, escorts are only used for urban travel. The automobile highway fatality rate, 1 x 10^{-8} per kilometer, was used to calculate escort traffic fatalities. The escort fatality calculation included the urban kilometers traveled , which were not multiplied by two. In this case, the assumption was made that once the escort vehicle escorted the loaded transport vehicle through the urban area, it would be used for other municipal safety tasks; therefore, calculating the distance back to the escort starting point was not appropriate. In addition, no escort would be required when the vehicle returns through the urban area with an empty cask.

- Truck highway fatality rates (DIRS 103455-Saricks and Tompkins, 1999, Table 4) are assumed to apply for heavy-haul trucks. For the Proposed Action using heavy-haul truck transport, multiple escort vehicles would be required for all travel (rural, suburban, or urban zones) as a safety precaution. For the typical heavy-haul truck convoy, there would be two lead escort vehicles and two trailing escort vehicles. Before and after the convoy, one vehicle would have the warning signs and the second (a state patrol vehicle) would aid in traffic control. For the naval SNF shipments, there would be an additional naval escort vehicle. Because the heavy haul truck would be overweight and a wide load regardless of whether the cask is full or empty, it is assumed that the empty convoy would have the same number of escort personnel as the convoy hauling SNF or HLW to the proposed repository. Only one heavy-haul vehicle is assumed to be in any single convoy. Fatality rates on upgraded Nevada highways would be the same as rates on U. S. primary highways.

- For alternatives involving transport by rail, fatality rates for general rail freight (DIRS 103455-Saricks and Tompkins, 1999, Table 6) apply to both common carriers and dedicated trains. The fatal accident rate is based on two-way travel for both the cask car and the escort car because both cars must be transported between the place of origin and the proposed repository with SNF and HLW. Both cars are assumed to have the same fatal accident involvement rate. Within each state, it is assumed that the one-way shipment distance for transporting SNF and HLW would be multiplied by the state-specific fatal accident rate for railcars, the sum of which would be multiplied by 4.2.

- No escorts are assumed for barge transport.

- Assumptions about the accident rate for the transportation of nonradioactive materials to the repository for its construction and operation, and for the transportation of site-generated waste from the repository, are discussed in Section 6.0.

- The round-trip distance from the Las Vegas valley to the repository was considered for estimating commuter traffic fatalities. Half of these traffic fatalities were assumed to occur among members of the general public and half among the commuting workers. This analysis is also found in Section 6.0.

5.3.1.4 Software

The SNF and HLW shipment and escort fatality estimates were made using the Microsoft® Access database described in Appendix E. The fatality estimates associated with commuter traffic and the movement of other materials to the repository were estimated using Microsoft® Excel spreadsheets. The Access and Excel programs used were part of the Office Professional

2000 Software Suite, were ran on either Pentium III® or Pentium IV® computers using a Windows 2000 Professional operating system.

5.3.1.5 Calculation/Analysis and Results

Potential traffic fatalities from SNF and HLW transportation were calculated by multiplying the appropriate accident rates by the kilometers per shipment in each state and the number of shipments from each site, using the transportation database described in Appendix A. The assumptions listed in Section 5.3.1.3 are built into the calculations. The results obtained from the database calculations are shown in Section 7.5. The potential traffic fatalities associated with the transport of supply materials to the repository, from the transport of site-generated waste to a nearby existing disposal facility and as a result of commuter travel, are presented in Section 6.5. Spreadsheets were used to calculate these fatality estimates.

5.3.2 RADIOLOGICAL ACCIDENT RISK

This section develops the analysis of collective population risks from accidents that could happen when SNF and HLW are transported. Figure 5-1 is a diagram of the parameters and models used in this calculation.

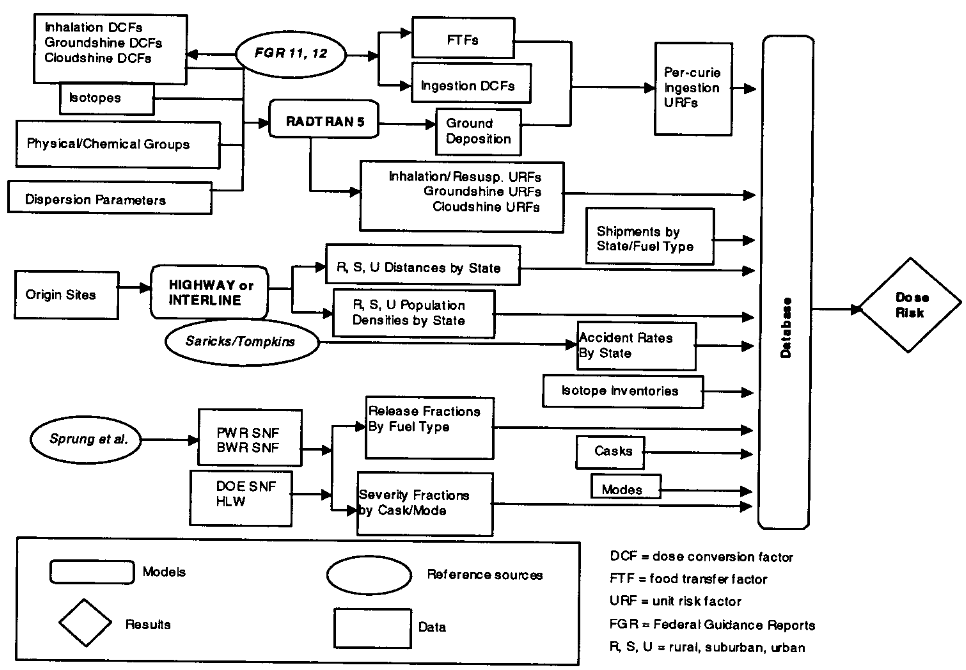

Figure 5-1. Diagram of parameters and information flow for the accident dose risk calculation.

The health impacts of a transportation accident involving radioactive material depend on the amount of material released into the environment (or the amount of shielding lost). The quantity of radioactive material released depends, in turn, on (1) the ability of the transportation cask to withstand the mechanical and thermal stresses of an accident, and (2) the behavior of the fuel in an accident. This section is therefore primarily concerned with modeling cask behavior and SNF and HLW behavior under accident conditions.

Section 5.3.2.1 briefly describes the casks (packaging) and the characteristics of the SNF and HLW that could be transported to the repository. This section also describes how the 33 DOE SNF and HLW types are grouped for analysis, and includes a brief description of each fuel and waste type. Section 5.3.2.2 discusses the methods used in the analysis, including development of accident severity categories and potential release fractions, as well as the RADTRAN accident risk calculations. Section 5.3.2.3 discusses the assumptions about the behavior of the DOE SNF and HLW (as compared to PWR behavior) in transportation accidents and the assumptions made about RADTRAN input parameters. Section 5.3.2.4 describes the computer software/models used in the analysis. Section 5.3.2.5 presents the results of the analysis in terms of the accident severity categories and release fractions, and the per-curie isotope unit risk factors. Section 5.3.2.6 discusses the transportation accident analysis involving loss of shielding.

5.3.2.1 Characteristics of the Casks and Fuels

5.3.2.1.1 Transportation cask characteristics.

All waste designed for the proposed Yucca Mountain repository would be shipped in Type B packages, which are designed to withstand a stringent set of test conditions (10 CFR Part 71 Subpart E). If the accident environment exceeds these design test conditions, some radioactive material may be released. This section discusses release mechanisms and probabilities, and possible amounts of materials released.

Sprung et al. (DIRS 152476-Sprung et al. 2000, Chapters 4 through 7) evaluated the behavior of two rail cask types (steel-lead-steel and monolithic steel) and two truck cask types (steel-lead-steel and steel-depleted uranium-steel) for PWR and BWR spent fuel, in order to encompass differences attributable to the selection of different cask designs. The depleted uranium truck cask is the most modern cask and has the highest capacity; it is the most likely design to be used for truck transportation. The steel-lead-steel rail cask could have slightly larger releases in a severe accident than the monolithic steel cask.

5.3.2.1.2 SNF and HLW characteristics.

The majority of the SNF intended for the Yucca Mountain repository would be PWR or BWR spent fuels from commercial nuclear power plants. The behavior of PWR and BWR fuels in the severe accident environment has been addressed in two previous studies: DIRS 101828 (Fischer et al. 1987, all) and DIRS 152476 (Sprung et al. 2000, all).

DOE has identified 33 additional waste types that could be transported to the proposed repository site. It is possible that some of the 33 additional waste types would be transported in casks somewhat different from PWR and BWR casks. However, the analysis in Sprung et al. (DIRS 152476-2000, Chapter 7) shows that performance differences among cask designs are small. Because of these small differences, the performance of the PWR truck and rail casks will be used as a basis for analyzing the severe accident risk for casks containing all the other waste forms that might be shipped to the repository. The PWR truck and rail release models will be modified to take into consideration the different properties of the waste form being analyzed.

Table 5-12 lists the 33 waste types that might be shipped to the proposed Yucca Mountain Repository. Waste types with similar characteristics and behavior are grouped in the analysis. The first column gives the database symbol for each waste type, and the second column lists the description for each waste type. The third column lists the tables in this calculation package that give the severity and release fractions for the waste types. The fourth column lists the reference fuel type: the fuel whose behavior either (1) most closely resembles that of the specific SNF or

HLW or (2) could result in larger potential releases in an accident than the other fuels in the group.

The isotope inventory of each waste type is presented in the Draft EIS (DIRS 105155-DOE 1999, Appendix A). The waste types were grouped into 10 groups in order to reduce the complexity of the accident risk analysis.

5.3.2.1.2.1 DOE spent fuel types analyzed as PWR fuel. This group includes PWR fuel and DOE fuel types 4, 11, and 12. DOE SNF type 4 fuel is ceramic fuel clad in corrosion-resistant material; its behavior closely resembles that of PWR fuel. DOE SNF fuel types 11 and 12 are mixed oxide and uranium-thorium oxide fuels, respectively.

Table 5-12. List of DOE SNF and HLW types. (1 of 2)

Database Symbol	Description	Table of Severity/Release Fractions	Reference Fuel Type
P	PWR Spent Fuel	5-21, 5-23, 5-25, 5-27	P
B	BWR Spent Fuel	5-22, 5-24, 5-26, 5-28	B
1	DOE Uranium Metal	5-31, 5-32	1
2	DOE Uranium-Zirconium	5-31, 5-32	1
3	DOE Uranium-Molybdenum	5-31, 5-32	1
4	DOE Uranium Oxide Intact	5-21, 5-23, 5-25, 5-27	P
5	DOE Uranium Oxide Failed/Declad	5-29, 5-30	5
6	DOE Uranium Aluminide	5-35, 5-36	6
7	DOE Uranium Silicon	5-35, 5-36	6
8	DOE Thorium-Uranium Carbide High-integrity	5-37, 5-38	8
9	DOE Thorium-Uranium Carbide Low-integrity	5-39, 5-40	9
10	DOE Plutonium-Uranium Carbide non-graphite	5-29, 5-30	5
11	DOE Mixed Oxide	5-21, 5-23, 5-25, 5-27	P
12	DOE Uranium-Thorium Oxide	5-21, 5-23, 5-25, 5-27	P
13	DOE Uranium-Zirconium Hydride (TRIGA)[a]	5-41, 5-42	13
14	Sodium-Bonded	5-31, 5-32	1
15	Naval Fuel	5-43	15
16	Miscellaneous (declad fuel, or fuel with failed clad)	5-31, 5-32	1
HH	Hanford HLW	5-44. 5-45	HLW
IH	INEEL HLW	5-44. 5-45	HLW
SH	Savannah HLW	5-44. 5-45	HLW
WH	West Valley HLW	5-44. 5-45	HLW
AWC	Argonne West Ceramic	5-44. 5-45	HLW
AWM	Argonne West Metal	5-44. 5-45	HLW
NS	Naval SPAR Waste	5-33, 5-34	5
HS	Hanford SPAR Waste	5-33, 5-34	5
IS	INEEL SPAR Waste	5-33, 5-34	5

Table 5-12. List of DOE SNF and HLW types. (2 of 2)

Database Symbol	Description	Table of Severity/Release Fractions	Reference Fuel Type
OS	Oak Ridge SPAR Waste	5-33, 5-34	5
WS	WV SPAR Waste	5-33, 5-34	5
SS	Sealed Source GTCC Waste	5-33, 5-34	5
GC	GTCC Waste	5-33, 5-34	5
O	Other GTCC Waste	5-33, 5-34	5
S	Special Waste	5-33, 5-34	5

a. TRIGA = Training Research Isotopes-General Atomic.

5.3.2.1.2.2 DOE SNF analyzed as type 1 fuel. This group includes fuel types 1, 2, 3, 14, and 16. DOE SNF types 1, 2, and 3 consist primarily of uranium or uranium alloy fuels clad in zirconium. Most of the type 1 SNF is zirconium-clad metallic uranium fuel discharged from the Hanford N-Reactor. Type 2 fuel is uranium-zirconium alloy fuel clad in zirconium and type 3 is uranium-molybdenum fuel clad in zirconium.

Metallic uranium undergoes a phase transition at 655 °C that may be enough to rupture the zirconium cladding on the fuel. Alloying with zirconium in fuel type 2 and plutonium in fuel type 14 lessens the effect of the phase transition, and alloying the metallic uranium with molybdenum in fuel type 3 eliminates the phase transition. Based on the phase transition data, type 1 fuel is expected to have slightly larger potential releases, and its performance in a canister is assumed to encompass the behavior of fuel types 2 and 3.

Fuel types 1, 2, and 3 would be shipped in a sealed canister inside the Type B transport cask. In the transportation accident environment, credit is taken for the canister but not for the cladding, because of the uncertain condition of the clad. DOE SNF types 14 (sodium-bonded fuel) and 16 (miscellaneous) can also be grouped with fuel types 1, 2, and 3. Both are metallic fuel and would be shipped in canisters. Some fuel type 16 is bare fuel.

5.3.2.1.2.3 DOE SNF modeled as failed fuel. This group includes fuel types 5 and 10, and SPAR and GTCC waste. DOE SNF type 5 fuel is ceramic fuel with clad that has failed or has been removed. It would be shipped in a DOE SNF canister. For these reasons, it is modeled separately from PWR fuel.

DOE SNF type 10 is a plutonium-aluminum carbide fuel. This is a non-graphite fuel type, and its behavior in severe accidents would be bounded by canisterized failed fuel (DOE SNF type 5).

Other DOE SNF categories of waste that would also be shipped in canisters have either no clad or clad of unknown integrity; they are therefore grouped with fuel type 5. These include all the SPAR waste generated at several sites, GTCC waste, and special waste.

5.3.2.1.2.4 Aluminide and silicide fuels. This group consists of DOE SNF types 6 (uranium aluminide) and 7 (uranium silicide). Both would be shipped in canisters because of the uncertain condition of the clad. Both are thought to have similar performance in the severe transportation accident environment. Because there is more experimental data on the performance of uranium aluminide fuel (type 6), its performance is used to also represent uranium silicide fuel in the severe transportation accident environment.

5.3.2.1.2.5 High integrity high-temperature gas-cooled reactor SNF (type 8). This is a high-integrity thorium-uranium carbide fuel.

5.3.2.1.2.6 Low integrity high-temperature gas-cooled reactor SNF (type 9). This is a low-integrity thorium-uranium carbide fuel. It is modeled separately from fuel type 8 to take into consideration the differences in integrity.

5.3.2.1.2.7 TRIGA fuel. DOE SNF type 13 is TRIGA reactor spent fuel; it is modeled separately from the other fuel types. It is a zirconium hydride-clad fuel, and its behavior is unique. The behavior of TRIGA fuel is described in Sections 5.3.2.2. and 5.3.2.3.

5.3.2.1.2.8 Naval SNF. DOE SNF type 15 is naval fuel. Release fractions are presented in Section 5.3.2.5.2.6.

5.3.2.1.2.9 HLW. The remaining fuel types presented in Table 5-12 are vitrified high-level waste. While the different vitrified waste types have different isotopic inventories, their behavior in the severe transportation environment would not be affected by the inventory differences and they are modeled the same.

5.3.2.1.2.10 BWR and PWR SNF. BWR and PWR SNF are analyzed extensively in Sprung et al. (DIRS 152476-2000, Chapters 4, 5, 6, and 7). Results are given in Section 5.3.2.5.

Sections 5.3.2.2, 5.3.2.3, and 5.3.2.5, respectively, discuss the methods, assumptions, and results for each waste type listed in Table 5.12. The discussion of the assumptions and results is grouped and presented in the order shown in the preceding paragraphs.

5.3.2.2 Method

The major elements of the total calculation of accident dose risk are shown in Figure 5-1. This section discusses analysis methods with reference to the elements shown in Figure 5-1. The order of discussion is:

1. Methods of analysis discussed in other sections of the calculation package
2. Methods for estimating severity fractions
3. Methods for estimating release fractions
4. Methods involving RADTRAN 5 analyses and use of the database: population dose and dose risk

5.3.2.2.1 Methods of analysis discussed in other sections of the calculation package. As Figure 5-1 shows, the route distances and population densities, shipment data, and cask types and capacities are input to the database. Shipment data are analyzed in Section 2.0 of this calculation package. Origin sites, population densities, and routes are analyzed in Section 3.0. Cask types are discussed briefly in Section 5.3.2.1.1. Cask types and capacities, and route, population density, and mode data are presented in data tables in the database itself on the accompanying compact disk.

5.3.2.2.2 Methods for estimating severity fractions: reduction of the 19 truck and 21 rail cases in Sprung et al. (2000) to six accident severity categories. Sprung et al. 2000 (DIRS 152476-Chapter 7) develops severity fractions (conditional probabilities) and release fraction estimates for gases, cesium, ruthenium, particulates, and crud for 21 rail and 19 truck cases. Every radionuclide belongs to one of these material types. The 21 rail and 19 truck cases are shown in Figures 5-2 through 5-5 (Section 5.3.2.5). This section describes the method for reducing the 21 rail and 19 truck cases to six accident severity categories. The six categories developed in this analysis are called "accident severity categories" to avoid any confusion between nomenclature used in Sprung et al. (2000, all) and in the database.

The probability for the new accident severity category is estimated using the following equation:

$$P_{Sci} = \sum_{j} P_{Cj} \qquad \text{Eqn. (5-1)}$$

where:

j = the cases included in severity category I

P_{Cj} = the case j probability

P_{Sci} = the accident severity i probability

The probability weighting of the release fractions is calculated using the following equation:

$$RF_{Sci,m} = \frac{\sum_{j,m} RF_{Cj} * P_{Cj}}{P_{Sci}} \qquad \text{Eqn. (5-2)}$$

The use of the "i" and "j" subscripts in Equation 5-2 is the same as that used for the probability calculation in equation 5-1. The "m" subscript has been added to Equation 5-2 to represent the five material classification types used in Sprung et al. (DIRS 152476-2000, pp. 7-30 to 7-46). The term "RF" is the fraction of the material in the cask released for a given material type.

The universe of accidents can be divided into any number of accident severity categories, and any number of severity categories can be reduced (or expanded) to a different number of categories. Grouping cases to be placed in a single accident severity category does not depend on the value of the conditional probabilities (severity fractions) of the cases. In this analysis, when grouping cases to be placed in an accident category, an effort was made to preserve some of the risk characteristics associated with the 19 truck and 21 rail cases. The grouping of cases into severity categories is shown in Table 5-13.

Table 5-13. Grouping of cases into six accident severity categories.[a]

Accident Severity Category	Rail Accident Cases	Truck Accident Cases
1	21	19
2	1, 4, 5, 7, 8	2, 3
3	20	18
4	2, 3, 10	1, 5, 6, 8
5	6	4
6	9,11,12,13,14,1516,17,18,19	7,9,10,11,12,13,14,15,16,17

a. From Sprung et al. 2000 severe accident cases (DIRS 152476-Tables 7.10 and 7.11 and pp. 73 to 76).

The rationale for the grouping of cases is as follows:

- Category 1 is the no-release case, truck case 19 and rail case 21.
- Category 3 is the fire-only scenario, rail case 20 and truck case 18.
- Category 4 includes cases in which the cask is impacted at a high velocity but the fire duration is relatively low. Release for this category is controlled by clad failure from impact and not from heat.
- Category 5 includes rail case 6 and truck case 4: a moderate impact but a severe fire, sufficient to rupture the fuel clad which did not fail on impact.
- Category 6 was assigned to a grouping of cases that represented probabilities of occurrence less than 10^{-8} per accident.
- Category 2 contains the remaining cases that are not included in any other severe accident category. These are cases with impact velocities less than 60 miles per hour for the truck case and less than 90 miles per hour for the rail case, and have fire durations that not severe enough to rupture the fuel clad.

Using Equations 5-1 and 5-2, six severity fractions were developed for the four generic casks analyzed in Sprung et al. (DIRS 152476-2000, pp. 73-76).

5.3.2.2.3 Methods for estimating release fractions. The amount of material released in an accident depends on both the conditional probability that the accident is of a particular severity (the severity fraction) and the release fraction. This section discusses the derivation of release fractions for the nine groups of DOE SNF and HLW. Release fractions are functions of the physical and chemical behavior of a radionuclide rather than its radiological behavior. Therefore, all of the radionuclides in the transported material belong to one of the following physical/chemical groups: particulate matter, crud, noble or ideal gas, cesium (semivolatile substances), and ruthenium. Sprung et al. (DIRS 152476-2000, Chapter 7) provides release fractions for 21 rail and 19 truck cases. This analysis is based on six accident severity categories.

5.3.2.2.3.1 Estimating release fractions for DOE SNF types analyzed as PWR fuel. The release fractions for these fuels are given in Sprung et al. (DIRS 152476-2000, pp. 73-76) for six accident severity categories. Reduction of the Sprung et al. release fractions to those for six accident severity categories is described in Section 5.3.2.2.2.

5.3.2.2.3.2 Estimating release fractions for DOE SNF analyzed as type 1 fuel, failed fuel, and aluminide and silicide fuels. The fuels in this group are shipped in canisters in spent fuel casks. Release fractions for them are derived by modifying the model of PWR fuel behavior (DIRS 152476-Sprung et al. 2000, Chapter 7). Three types of modifications were made:

1. Canister failure was analyzed instead of fuel rod failure.

2. PWR SNF is pressurized, while canistered fuel is generally not pressurized, and the effect of both impact and heating on gas expansion is different for pressurized fuel than for canistered fuel. Therefore, gas expansion factors used in calculating release fractions were adjusted.

3. Different fuel types would release different quantities of material in a potentially severe accident environment.

The major changes in the parameter values of Sprung et al. (DIRS 152476-2000, Chapter 7) that were made for this analysis are described in Appendices C and D. Appendix C provides the basis for replacing the PWR clad failure model by a DOE SNF canister failure model. The analysis in Appendix D shows that the DOE SNF canister will not fail when heated to 1,000 °C, while the PWR model fails the clad at 750 °C. The impact speeds at which the canister is assumed to fail also differ from the PWR clad failure impact speeds estimated in Sprung et al.

The following paragraphs first describe the modifications to the gas expansion model of Sprung et al. (DIRS 152476-2000, Section 7.3) and then present a brief overview of changes to the relevant equations.

The gas expansion model used to estimate release fractions considers two driving forces for release: the gas release if and when the clad or canister fails, and the release caused by relief of increased gas pressure inside the cask as the cask heats internally in a fire. If the canister does not fail, there is no release even if the cask is breached. If canisters fail, the fraction of radionuclides released from internal canister space is assumed to equal the fraction of gases displaced. If the cask is then breached, gas in the cask, and gaseous, vaporized, and very fine particulate radionuclides would be released until the pressure in the cask was the same as the ambient (atmospheric) pressure.

The behavior of the DOE SNF canister design (DIRS 137713-DOE 1998, all) in the accident environment (discussed in Appendix D) was developed from the results of impact tests performed on a HLW canister (DIRS 102088-Smith and Ross 1975, pp. 27–44). As shown in Appendix D, the probability that the SNF canister fails from impact with an unyielding surface at between 30 to 60 miles per hour is 2 percent. This probability increases to 20 percent for impacts between 60 and 90 miles per hour, to 50 percent for impacts between 90 and 120 miles per hour, and to 100 percent for impacts above 120 miles per hour. The analysis in Appendix D also shows that the canister design is capable of being heated to 1,000 °C without failure. Thus, a fire-only accident would not result in any release unless the internal cask temperature exceeded 1,000 °C. Because the canister would not fail from thermal stress alone, no pressure spikes inside the cask, such as those assumed to occur in the PWR model of Sprung et al., would occur when the temperature exceeded 750 °C. For the fire cases, the releases would be driven by thermal expansion, which would lead to smaller estimated releases.

If the canister were to fail on impact, pressure inside the canister would provide the driving force for releasing from the cask any radioactive materials that had been released from a canister into the cask following the impact. In accident scenarios without fire, the temperature inside the cask at the time of the accident is assumed in Sprung et al. (DIRS 152476-2000, p. 7-21) to be 300 °C. The internal pressure in the canister would be 2.43 atmospheres, based on the assumption that the canister is at room temperature and the internal pressure is 4 psig after the closure weld has been completed (DIRS 137713-DOE 1998, p. 6). This pressure of 2.43 atmospheres provides a driving force for release. If additional heating were to occur in the ensuing fire, then additional gas displacement from gas thermal expansion would also occur. However, if the fuel is not itself pressurized, there would be no additional gas sources to drive more material from the cask. This is the major difference between the model results from canister failure and model results from the PWR model described in DIRS 152476 (Sprung et al. 2000, Section 7.3).

The complete derivation of the expansion factors for canistered fuel is provided in Appendix C. A brief overview is given here. Sprung et al. (DIRS 152476-2000, p. 7-24) presents the fraction of material released as

$$RF_T = fr_i * f_{RCi} * (1 - f_{di}) * f_{esi} + (1 - fr_i) * f_{RCt} * (1 - f_{dt}) * f_{et} \quad \text{Eqn. (5-3)}$$

where:

- fr_i = the fraction of the clad failed on impact
- f_{Rci} = the fraction of the fuel component released to the cask on impact
- f_{di} = the fraction of the fuel component deposited on the inside surfaces of the cask
- f_{esi} = a series of expansion terms used to estimate the fraction of the material available for release from the initial impact that is subsequently released from the cask
- f_{RCt} = the fraction of the fuel component released from thermal heating
- f_{dt} = the fraction of the fuel component deposited on the inside surfaces of the cask during thermal heating
- f_{et} = the thermal expansion terms used to estimate the fraction of the material made available for release from thermal heating that is subsequently released from the cask

The thermal expansion terms f_{et} are related to pressures and temperatures in the cask as

$$f_{e1} = \left[\frac{p_f T_s}{p_s T_f}\right] \quad \text{Eqn. (5-4)}$$

where the subscripts s and f refer, respectively, to starting and final temperature and pressure. In Sprung et al. (DIRS 152476-2000, Chapter 7), f_{esi} takes values for f_{e1}, f_{e2}, f_{e3}, corresponding to different fractions of clad failure at different impact speeds and the effects of fires subsequently heating the fuel failed on impact, and f_{et} takes values f_{e3} and f_{e4} corresponding to different fractions of clad failure during heat-up in a fire and differences in the final temperature attained. In the PWR and BWR model, clad that has not failed on impact, (1-fr_i) in Equation 5-3, fails under thermal stress at 750 °C. This failure is captured in f_{e3}.

For canister failure, both the impact-driven potential releases and the thermally driven potential releases are proportional to the fraction of canisters assumed to fail, fr_i. Moreover, thermal expansion is represented by a single term. Equation 5-3 becomes

$$RF_T = fr_i * f_{RCi} * (1 - f_{di}) * f_{ei} + fr_i * (1 - f_{RCi}) * f_{RCt} * (1 - f_{dt}) * f_{et} \qquad \text{Eqn. (5-5)}$$

where fr_i is the fraction of canisters failed on impact instead of the fraction of fuel clad failed. The terms f_{ei} are expansion factors following impact and take values $f_{e1}, f_{e2}, f_{e3},$ for different fractions of canisters that could fail at different impact speeds. The term $f_{et} = f_{e4}$ is the single expansion factor for thermal release since no additional canister failures would occur until well above 1,000 °C, the maximum fuel temperature modeled (see Appendix D). The expansion factors are the fractions of the gases that remain inside the cask. The detailed derivation of these expressions is provided in Appendix C, and the derivation of expansion factors for each DOE SNF reference fuel type is shown in the spreadsheet files in Attachment 532A.

The following example, from Sprung et al. (DIRS 152476-2000, pp. 7-25 and 7-26) rail cases 7, 8, and 9, illustrates the application of the expansion factors and the difference between the application to PWR fuel and the application to canistered fuel. Details of the calculation are presented in Appendix C and summarized in Table C-1.

- The first expansion factor f_{e1} is the result of impact. Case 7 involves seal failure on impact only at 60-mile-per-hour to 90-mile-per-hour impact speed and ambient temperatures. About 59 percent of the PWR fuel rod cladding could fail (DIRS 152476-Sprung et al. 2000, Table 5.17).

- Almost 75 percent, (1-0.274)*100, of the gas in the cask would be swept out with the initial failure, f_{e1}, because the fuel is pressurized. The other three expansion factors are all equal to 1, because there is no heating.

- For canistered fuel under these conditions, about half of the canisters could fail in this range of impact speeds (Section 5.3.2.2.3.1). The sealed canisters are not pressurized, so that less than 30 percent of the radioactive material present in the gas space would be released (see Appendix C, pp. C-3 to C-5), in contrast to the 75 percent that could be released from PWR pressurized fuel.

- Case 8 has the same impact speed range as case 7, but the internal cask temperature increases from 350 to 750 °C. The second expansion factor, f_{e2}, results from thermal gas expansion and represents the additional fraction of the remaining gas that would be retained. No additional PWR clad failures are postulated as the fuel heats from 350 to 750 °C, so the expansion factors are the same. Analysis at a different impact speed (as in case 10) would include an additional impact-related expansion factor, because there would be additional clad failures.

- Because the impact speed range is the same, the same fraction of canisters could fail from impact as for case 7. The additional heat would not fail additional canisters, so the second gas expansion factor would be the same as for PWR fuel.

- For PWR case 9, the third expansion factor, f_{e3}, represents the fraction of the remaining gas that is retained in the cask when the remaining 41 percent of the clad fails at 750 °C and is then subsequently heated to 1,000 °C. Only 0.167 of the material still remaining in the cask remains after the remaining clad fails and the fuel is heated to 1,000 °C.

- No additional failure from heating is assumed for the canistered fuel, so the fraction of the gas retained in the cask is much higher (0.804). The gas expansion factor in the canister model results only from thermal expansion of gas already released from the canister to the cask. In both the PWR and canister model, the fourth expansion factor is used in the thermal release calculation. As described in Appendix C, the definition of f_{e4} in the PWR model differs from that in the canister model, so no direct comparison is possible. In the canister model, $f_{et} = f_{e4}$ (see Equation 5-5).

Table 5-14 shows the difference in the expansion factors in modeling PWR fuel (from DIRS 152476-Sprung et al. 2000, p.7-24) and in modeling canistered metallic or alloyed uranium fuel for one example: the rail case following a 60- to-90-mile-per-hour impact and thermal heating (cases 1 though 17 in Figure 5-2). The derivation of these expansion factors for each DOE SNF reference fuel type is shown in the spreadsheet files in Attachment 532A.

Table 5-14. Expansion factors for rail accident scenarios for 60- to 90-mile-per-hour impact and thermal heating.

Case	f_{e1}		f_{e2}		f_{e3}		f_{e4}	
No.	PWR	Canister	PWR	Canister	PWR	Canister	PWR	Canister
1	0.298	0.774	1	1	1	1	1	1
7	0.274	0.713	1	1	1	1	1	1
8	0.274	0.713	0.609	0.609	1	1	1	1
9	0.274	0.713	0.609	0.609	0.167	0.804	0.304	0.804
17	0.274	0.713	0.609	0.609	0.167	0.804	0.304	0.804

Details of the application of the expansion factors for each fuel are shown in Attachment 532A on the compact disk. The files in Attachment 532A are listed in Table 5-15. The release fractions for DOE SNF, which were calculated using expansion factors for canistered fuel, are presented in Section 5.3.2.5.

5.3.2.2.3.3 Method for Estimating Release Fractions for High-temperature Gas-cooled Reactor Fuels. The method for estimating release fractions for these fuels is the same as for PWR fuel, as described in Sprung et al. 2000 (DIRS 152476-Chapter 7).

5.3.2.2.3.4 Method for Calculating TRIGA SNF Release Fractions. TRIGA fuel is made up of approximately 8 percent uranium and 92 percent zirconium hydride ($ZrH_{1.88}$). As a result of many hydride/dehydride cycles, the uranium-zirconium hydride matrix in the reactor would have been converted to a metal powder with an average particle size less than 10 microns. The release fraction resulting from the failure of a fuel rod containing a fine powder would be 0.003 (from the DOE handbook *Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities*) (DIRS 103756-DOE 1994, p. 4-73). Because there is no cesium and ruthenium volatilization at temperatures less than 750°C, this release fraction would be used for cesium and ruthenium as well as for particulates at less than 750 °C. The crud release fraction and the noble gas release fractions would be the same as those used for the PWR and BWR fuels. Any cesium released as a result of the initial impact but not released from the cask on either cask or seal failure would be volatilized once the temperature in the cask exceeds 750 °C. In a fire at 1,000 °C, if the canister, TRIGA fuel pins, and the cask are breached, volatile cesium and noble gases would be swept from the cask.

Table 5-15. Files in Attachment 532A.

DOE SNF Number	SNF Description	Spreadsheet Filename[a]
1	Metallic Spent Fuel	RF_UMETAL_R
2	Uranium-Zirconium	RF_UMETAL_T
3	Uranium-Molybdenum	
14	Sodium-Bonded Uranium and Uranium Plutonium Metal Alloy Fuel	
16	Miscellaneous	
5	Uranium Oxide Failed/Declad/Aluminum Clad Fuel	RF_FAILOX_R
		RF_FAILOX_T
10	Plutonium-Uranium Carbide, Nongraphite	RF_UPuC_R
		RF_UPuC_T
6	Uranium Aluminide Fuel	RF_AL_R
7	Uranium Silicide Fuel	RF_AL_T
8	Thorium-Uranium Carbide High Integrity Fuel	RF_HTGR-H_R
9	Thorium-Uranium Carbide Low Integrity Fuel	RF_HTGR-H_T
13	Uranium-Zirconium Hydride (TRIGA)	RF_UZrH_R
		RF_UZrH_T
15	Naval SNF	RF_Navy_R
HLW	Vitrified HLW	RF_HLW_R
		RF_HLW_T
11	Mixed Oxide Fuel	RF_PWR_R
12	Uranium-Thorium Oxide	RF_PWR_T
4	Uranium Oxide Intact	

a. The suffix *_R indicates transportation in a rail cask; *_T indicates transportation in a truck cask.

Details of the application of the expansion factors in calculating release fractions for TRIGA fuel are shown in Attachment 532A on the compact disk and discussed in Appendix C. The files in Attachment 532A are listed in Table 5-15. Release fractions for TRIGA fuel are presented in Section 5.3.2.5.

5.3.2.2.3.5 Estimating release fractions for naval SNF. Release fractions for this fuel were supplied to the analysis by the Navy Nuclear Power Program.

5.3.2.2.3.6 Method for Estimating Release Fractions for HLW. Neither noble gases nor crud are present in vitrified HLW. Cesium and ruthenium are chemically bound to silicon and boron in the glass matrix. The physical properties of vitrified HLW are similar to the properties of ceramic oxide fuel like PWR fuel, so the release fractions are estimated to be the same as the particulate release fractions for PWR fuel.

5.3.2.2.3.7 Summary of Methods for Estimating Release Fractions and Use in the Database. The derivation of expansion factors and release fractions for each of the DOE SNF and HLW reference fuel types is shown in the spreadsheet files in Attachment 532A.

In the database, the six accident severity categories and the associated release fractions are reduced to one set of release fractions using the same equations that reduced the 21 rail and 19 truck cases to the six accident severity categories. This set of accident severity categories and release fractions is then multiplied by the likelihood of the accident occurring, the number of assemblies in the cask, and the isotope inventory of the cask, to obtain per-shipment isotope-specific release risk terms for the rural, suburban, and urban population zones for the Proposed Action, Module 1, and Module 2.

5.3.2.2.4 Method for Calculating Accident Dose Risk Using RADTRAN 5. The dose consequence per curie of each isotope was calculated using RADTRAN 5 for the inhalation, resuspension, cloudshine (immersion), and groundshine. The equation used by RADTRAN 5 for the inhalation dose consequences for one isotope (adapted from DIRS 155430-Neuhauser et al. 2000, Section 5.3.2, equation 77) is

$$D_{inh} = Ci_i * NSHIP * \sum_L (PD_L * ACC_L * DIST_L) * \sum_j (CP_j * RF_{i,j} * AER_{i,j} * RESP_{Ii,j}) * IF * A_n * BR * Q * DCF_i$$

Eqn. (5-6)

where,

Ci_i	=	curies of the isotope per shipment
NSHIP	=	number of shipments
PD_L	=	population density on a route segment
ACC_L	=	accident rate on the route segment
$DIST_L$	=	length of the route segment
CP_j	=	conditional probability that the accident will be of a particular severity (severity fraction)
$RF_{i,j}$	=	release fraction of isotope i for severity fraction j
$AER_{i,j}$	=	aerosolized fraction of isotope i for severity fraction j
$RESP_{i,j}$	=	respirable fraction of isotope i for severity fraction j (particle size less than 10 microns)
IF	=	integral of the atmospheric dilution over all downwind areas
A_n	=	area of the nth downwind isopleth
BR	=	breathing rate
Q	=	unit conversion factors
DCF_i	=	the curie-inhaled-to-rem conversion factor for isotope i

The equation for resuspension dose (DIRS 155430-Neuhauser et al. 2000, equation 79) is the same as Equation 5-6, except that it includes a resuspension factor. The equation for cloudshine dose (DIRS 155430-Neuhauser et al. 2000, equation 81) is also the same as Equation 5-6, except that it replaces the inhalation dose conversion factor with the immersion dose conversion factor. The subscript j takes values 1 to 6. The first summation sign indicates that the product of accident rate, route segment length, and population density is summed over all route segments. Accident rates (DIRS 103455-Saricks and Tompkins 1999, Tables 4 and 6) are presented for each state. The products of rural, suburban, and urban population densities (Section 3.0) and rural, suburban, and urban route segment lengths (Section 3.0) are summed for each state. The resulting product for each state is then summed over a route for each transportation mode.

The second summation sign indicates that the product of conditional probability (severity fraction) and release fraction is summed over all six accident severity categories for each isotope.

In this analysis, all radioactive material released was assumed to be both aerosolized and respirable, so that AER = RESP = 1.

Equation 5-6 was divided into database factors (DF_i) and unit risk factors (URF_i) for each isotope. The database factor includes the parameters found in tables in the database, and the unit risk factor is calculated by RADTRAN 5. The equation for the database factor is:

$$DF_i = Ci_i * NSHIP * PD_L * ACC_L * DIST_L * \sum_j (CP_j * RF_{i,j}) \quad \text{Eqn. (5-7)}$$

Equation 5-7 represents the database factor for inhalation, resuspension, cloudshine, and groundshine dose risk. The unit risk factors for each of these is different. For inhalation, the unit risk factor is:

$$URF_{inh,i} = IF * A_n * BR * Q * DCF_{inh,i} \quad \text{Eqn. (5-8)}$$

For immersion (cloudshine), the unit risk factor is:

$$URF_{imm,i} = IF * A_n * Q * DCF_{imm,i} \quad \text{Eqn. (5-9)}$$

For resuspension, the unit risk factor is:

$$URF_{resusp,i} = IF * A_n * BR * Q * RSP_i * DCF_{inh,i} \quad \text{Eqn. (5-10)}$$

where RSP_i is a resuspension factor (DIRS 155430-Neuhauser et al. 2000, equations 78 and 79).

For groundshine, the unit risk factor is:

$$URF_{grd,i} = IF * A_n * Q * GD_i * DCF_{grd,i} \quad \text{Eqn. (5-11)}$$

where GD_i is the ground contamination in curies/m^2 per curie released, and depends on the settling velocity of released particulate matter (DIRS 155430-Neuhauser et al. 2000, equations 85 and 86).

The ingestion database factor and unit risk factor are both different from these factors for other exposure pathways. The database factor for ingestion is:

$$DF_{ingest,i} = Ci_i * NSHIP * FTF_{L,i} * ACC_L * DIST_L * \sum_j (CP_j * RF_{i,j}) \quad \text{Eqn. (5-12)}$$

where FTF_i is the state-specific, isotope-specific food transfer factor (DIRS 104800-CRWMS M&O 1999, all). The food transfer factors are isotope- and state-specific because the food production differs among the states through which the SNF and HLW might be transported. States with intensive farming have much larger food transfer factors than states where most of the land is fallow. Both the dose consequence and food transfer tables are part of the database, and both are based on one curie of the isotope being released or being passed through the food chain. The population consuming the particular food is included in the food transfer factor, so that the ingestion database factor is not multiplied by the population density.

The ingestion unit risk factor is:

$$URF_{ing,i} = IF * A_n * Q * GD_i * DCF_{ing,i} \qquad \text{Eqn. (5-13)}$$

The ingestion unit risk factor was not calculated by RADTRAN 5, although the calculation used the ground deposition output from RADTRAN 5. The calculation is shown in the spreadsheet file Grounddep_rev1.xls in Attachment 532B. The isotope-specific and physical/chemical group-specific RADTRAN files are also in Attachment 532B and are listed in Table 5-54.

As shown in Figure 5-1, for the list of isotopes being considered in the analysis, the dose conversion factors needed to calculate the per-curie unit risk factor for each isotope are taken from Federal Guidance Reports 11 (DIRS 101069-Eckerman et al. 1988, all) and 12 (DIRS 107684-Eckerman and Ryman 1993, all). The isotopes in the inventory are also classified according to physical/chemical behavior in one of the physical/chemical groups (noble gases, cesium, ruthenium, particulate matter, and crud), which were used to determine the release fraction.

5.3.2.3 Assumptions

The following subsections list the major assumptions made in developing release risk, dose consequence, and accident dose risk estimates for each waste type being considered in this analysis.

For accident rates and accident risk, it was assumed that the average number of railcars involved in an accident would be 4.2. Thus, the railcar accident rates presented in DIRS 103455 (Saricks and Tompkins 1999, Table 6) have been multiplied by 4.2.

Risk is the product of likelihood of an accident and its consequences. Both collective accident population risks and collective accident consequences are expressed in person-rem or LCFs, because a probability has no units. Throughout this document, the product of likelihood of a release (for the 24-year period of shipments to the repository) and dose consequence is called a "dose risk."

5.3.2.3.1 Assumptions used in release fraction calculations. This subsection discusses the modeling of each group of DOE SNF and HLW fuel types (see fuel type designations in Table 5-12).

5.3.2.3.1.1 DOE SNF fuel types analyzed as PWR. These fuel types include PWR, BWR, and DOE SNF types 4, 11, and 12. It was assumed that the release risk modeling assumptions presented in Sprung et al. 2000 (DIRS 152476-Section 7.3) were valid. The assumption was made that for rail transport all the PWR and BWR fuel would be shipped in the steel-lead-steel rail cask and for truck transport both would be shipped in the steel-depleted uranium-steel truck cask. The behavior of SNF types 4, 11, and 12 in an accident environment are assumed to be bounded by PWR fuel because all three fuel types are considered to have intact cladding and have a lower internal pressure than PWR fuel pins.

5.3.2.3.1.2 DOE SNF analyzed as fuel type 1. These fuels include fuel types 1, 2, 3, 14, and 16. The releases from these fuel types in the severe transportation accident environment are assumed to be no greater than releases from fuel type 1. Types 2 and 3 fuel should have better performance because when metallic uranium is alloyed with zirconium in type 2 fuel and with molybdenum in type 3 fuel, the effect of the uranium phase transition at 655 °C is reduced or, in the case of the uranium-molybdenum alloy, completely eliminated. Fuel types 14 and 16 can be included with these fuel types because both are predominantly metallic fuel with no clad or with breached clad, and no credit is being taken for the cladding when modeling the behavior of these fuel types. All would be shipped in a DOE SNF canister; credit is being taken for the canister behavior in the accident environment. Modeling assumptions are listed in Table 5-16.

Table 5-16. Release risk calculation assumptions for DOE SNF types 1, 2, 3, 14, and 16.

Model Element	Modeling Assumption and Basis
Fuel Release Fraction from Impact	The PWR fuel pellet release fraction takes into consideration the unknown amount of oxidation.
Fuel Release Fraction from Thermal Stress	Metallic uranium undergoes a phase transition at 655°C that may result in rupture of the zirconium cladding. Thompson and Beckerley (DIRS 156940-1973, p. 561-562) shows that at 1,000°C (1,273 K), the maximum temperature modeled in the transport analysis, 80% of the uranium will oxidize in 20 minutes and that during the oxidization, approximately 20% of the cesium and 6% of the ruthenium will be released from the fuel.
Clad or Canister Release	All SNF will be in sealed canisters; the canister release model applies. Canister overpressure after welding is assumed to be 4 psig (DIRS 137713-DOE 1998, p. 6). Canister failure is expected only from impact, none from exposure to fire, as discussed in Appendix D.
Fraction of radionuclides deposited in cask inner surfaces	Same as PWR deposition fraction.
Cask Damage	Same as cask loaded with PWR fuel.
Fraction of deposited material volatilized in fire when two areas of the cask are breached	No volatilization of the deposited ruthenium is assumed to occur in cases where the fuel is heated to 1,000°C and there is a double breach of the cask (rail cases 16-19 and truck cases 14-17) (DIRS 152476-Sprung et al. 2000, pp. 73 to 76). The uranium present in the cask will scavenge any oxygen that enters the cask, suppressing the oxidation of the ruthenium to its more volatile higher-valence oxides. Volatilization of the deposited cesium is assumed to occur under the same conditions.
Release fraction from cask	The canister failure model is used. When the canister is welded shut, the internal pressure will be 4 psig (DIRS 137713-DOE 1998, p. 6), and the temperature inside the canister will be 27°C (300 K). During shipment the temperature of the fuel in the canister will be 300°C (573 K), and the pressure inside the canister at failure depends on the temperature at failure and the ideal gas law. This canister pressure provides the only driving force and is the basis for estimating the cask release fractions.

5.3.2.3.1.3 DOE SNF modeled as failed fuel. This includes types 5 and 10, SPAR, and GTCC waste. Based on the descriptions of these fuels and wastes, the performance will be bounded by modeling all these fuel types as failed fuel. Because all will be placed in the DOE

SNF canister, the canister will limit the release in many cases; where the canister is breached, the absence of pressurized fuel will reduce the release to below that of PWR fuel. SPAR and GTCC waste would not contain either crud or noble gases. The major assumptions are listed in Table 5.17.

Table 5-17. Release risk calculation assumptions for DOE SNF types 5, 10, SPAR, and GTCC waste.

Model Element	Modeling Assumption and Basis
Fuel Release Fraction from Impact	Fuel type 5 is failed oxide fuel, so the PWR fuel pellet release fraction is used. Oxide release fractions bound other fuel types.
Fuel Release Fraction from Thermal Stress	Fuel type 5 is failed oxide fuel, so there will be no pressure-driving force. However, the fraction of the clad damaged could be the entire length of the clad rather than the 0.25-inch section assumed for PWR fuel. The effect of the differences essentially cancel, and it is reasonable to use the PWR release fractions. Oxide release fractions will bound other fuel types.
Clad or Canister Release	All SNF categories will be in sealed canisters, so the canister release model is used. Canister overpressure after welding is assumed to be 4 psig (DIRS 137713-DOE 1998, p. 6). Canister failure is expected only from impact, none from exposure to fire, as discussed in Appendix D.
Fraction of radionuclides deposited in cask inner surfaces	Same as PWR deposition fraction.
Cask Damage	Same as cask loaded with PWR fuel.
Fraction of deposited material volatilized in fire when two areas of the cask are breached	Same as PWR volatilization.
Release fraction from cask	The canister failure model is used; gas in the sealed canister provides the only driving force for release. See the discussion in Table 5-16.

5.3.2.3.1.4 Aluminide and silicide fuels. This includes DOE SNF types 6 and 7. The modeling assumptions are based on the behavior of type 6 fuel. Its is assumed to result in slightly larger potential releases in a severe accident than aluminum silicide fuel (type 7), thus eliminating the need for a separate model. The assumptions are shown in Table 5-18.

5.3.2.3.1.5 High-temperature gas-cooled reactor SNF. This category includes DOE SNF types 8 and 9. Slightly different modeling assumptions are used for these fuel types. Both these waste forms are high temperature gas reactor SNF in a graphite matrix. For type 9 fuel (but not type 8 fuel), all the particles are assumed to be breached; thus, the fuel material inside them is available for release. It is assumed that neither will be shipped in a canister that provides any impact or thermal resistance in a severe transportation accident. The release risk assumptions are presented in Table 5-19.

5.3.2.3.1.6 TRIGA SNF: DOE SNF type 13. The modeled behavior of the TRIGA reactor spent fuel (type 13) uses many of the same modeling assumptions used for failed fuel. The major differences are that TRIGA fuel is a fine powder of zirconium hydride and uranium; therefore, if the fuel rods breach, the release could be significant. Second, the zirconium hydride begins to exert a measurable hydrogen pressure at 350°C, and this pressure exceeds atmospheric pressure at 900°C. As described in Section 5.3.2.2.3.4, the models assume the hydrogen will sweep out most of the released material. The assumptions are listed in Table 5-20.

Table 5-18. Release risk calculation assumptions for DOE SNF type 6 and 7 fuels.

Model Element	Modeling Assumption and Basis
Fuel Release Fraction from Impact	The PWR fuel pellet release fraction takes into consideration an unknown amount of oxidation.
Fuel Release Fraction from Thermal Stress	The fuel release fractions used in this analysis are based on data presented in the *Savannah River K Reactor Probabilistic Safety Assessment* (DIRS 156762-Brandberry et al. 1992, pp. 5-25 and 5-26). At a temperature of 1,000 K, this reference indicates that for aluminum alloy fuel, all the noble gases and half of the cesium are released. The cesium release fraction increases to 0.99 at 1,400 °K. For this analysis, a cesium release fraction of 0.9 at 1,273 °K has been used. The release fractions for ruthenium and particulates were assumed to be the same as for PWR fuels.
Clad or Canister Release	All SNF categories will be in sealed canisters. The canister release model is used. Canister overpressure after welding is assumed to be 4 psig (DIRS 137713-DOE 1998, p. 6). Canister failure is expected only from impact, none from exposure to fire, as discussed in Appendix D.
Fraction of radionuclides deposited in cask inner surfaces	Same as PWR deposition fraction.
Cask Damage	Same as cask loaded with PWR fuel.
Fraction of deposited material volatilized in fire when two areas of the cask are breached	No volatilization of the deposited ruthenium is assumed to occur in cases where the fuel is heated to 1000 °C and there is a double breach of the cask (rail cases 16-19 and truck cases 14-17) (DIRS 152476-Sprung et al. 2000, pp. 73 to 76). The molten aluminum present in the cask will scavenge any oxygen that enters the cask, suppressing the oxidation of the ruthenium to its more volatile higher-valence oxides. Volatilization of the deposited cesium is assumed to occur under the same conditions.
Release fraction from cask	The canister failure model is used; gas in the sealed canister provides the only driving force for release.

Table 5-19. Release risk calculation assumptions for DOE SNF type 8 and 9 fuels.

Model Element	Modeling Assumption and Basis
Fuel Release Fraction from Impact	The release fraction for damaged particles is assumed to be the same as the PWR oxide fuel release fractions. Not all particles are assumed damaged. For type 8 fuel, the fraction of the fuel particles damaged on impact is assumed to be 0.1% for cask impacts with an unyielding surface ranging from 60 – 90 mph, and 1% for impacts greater than 90 mph. The fraction failed for type 9 fuel is assumed to be 100% at all impact velocities.
Fuel Release Fraction from Thermal Stress	The PWR thermal release fractions were used if the fuel particles were damaged by impact. It was assumed that particles not damaged on impact would not fail from thermal heating. They are designed to maintain their integrity in a higher-temperature reactor environment.
Clad or Canister Release	No canister is assumed. The pressure inside the cask at the time of the release is based on the assumption that the cask was closed at room temperature and atmospheric pressure. The fuel temperature during normal transport was assumed to be 300 °C. Thus, the pressure inside the cask at the time of cask failure by impact was assumed to be 1.91 atmospheres (13.3 psig).
Fraction of radionuclides deposited in cask inner surfaces	Same as PWR deposition fraction.
Cask Damage	Same as cask loaded with PWR fuel.
Fraction of deposited material volatilized in fire when two areas of the cask are breached	Same as PWR volatilization fraction.
Release fraction from cask	Gas pressure in cask from thermal heating is the only driving force for release. Pressure is based on closure at 27 °C at atmospheric pressure.

Table 5-20. Release risk calculation assumptions for DOE SNF type 13, TRIGA fuel

Model Element	Modeling Assumption and Basis
Fuel Release Fraction from Impact	The release fraction for the failed fuel rods will use the release fractions for rupture of a pressurized can containing powder (DIRS 103756-DOE 1994, p. 4-73)
Fuel Release Fraction from Thermal Stress	Above 900 °C, the zirconium hydride will have a vapor pressure above one atmosphere; if both the fuel clad and the canister are breached, any radioactive material present in the gas space in the cask will be released. It is estimated that the volume of hydrogen produced from complete decomposition of the fuel will exceed 250 cask volumes.
Clad or Canister Release	All SNF categories will be in sealed canisters, so the canister release model is used. It is assumed that canister overpressure after welding is 4 psig (DIRS 137713-DOE 1998, p. 6). Canister failure is expected only from impact, none from exposure to fire, as discussed in Appendix D.
Fraction of radionuclides deposited in cask inner surfaces	Same as PWR deposition fraction.
Cask Damage	Same as cask loaded with PWR fuel.
Fraction of deposited material volatilized in fire when two areas of the cask are breached	No volatilization of the deposited ruthenium is assumed to occur in cases where the fuel is heated to 1000 °C and there is a double breach of the cask (rail cases 16-19 and truck cases 14-17) (DIRS 152476-Sprung et al. 2000, pp. 73 to 76) The powdered uranium and zirconium present in the cask will scavenge any oxygen that enters the cask, suppressing the oxidation of the ruthenium to its more volatile higher-valence oxides. All deposited cesium is assumed to be volatilized as the 250 cask volumes of hydrogen sweep out the gas inside the canister.
Release fraction from cask	The canister failure model is used; gas in the sealed canister provides the driving force until the temperature reaches 900 °C. Above 900 °C, the hydrogen sweeps any material present in the gas space out of the cask.

5.3.2.3.1.7 HLW. The HLW canister design is somewhat different from that of the DOE SNF canister. These differences, described in Appendix C, show that while neither canister will fail when heated to 1,000 °C without impact, the HLW canister has slightly different failure thresholds for impact. Therefore, different model parameters are used for the HLW canister. As discussed in Section 5.3.2.1 (where each waste type is described), several DOE facilities are projected to generate HLW, and each facility's HLW has a unique radionuclide inventory. However, these differences in inventory are assumed to make no difference in the material release fractions. Thus, the same risk release model will be used for all HLW types. The differences will be captured in the dose consequence part of the calculation and carried into the accident risk calculation through that part of the model. Neither crud nor gases are assumed to be present in vitrified HLW, and potentially volatile radionuclides would be bound to the boron and silicon in the glass matrix. The assumptions are shown in Table 5-21.

Table 5-21. Release risk calculation assumptions for DOE HLW.

Model Element	Modeling Assumption and Basis
Fuel Release Fraction from Impact	For particulates, cesium, and ruthenium, the PWR particulate release fractions were assumed. Glass damage by impact is frequently equated to ceramic fuel impacts. No noble gases will be present in the waste form. The HLW is formed at 1,150 °C; at those temperatures, any noble gases would volatilize from the melt. In addition, there is no crud on the outside of the canister.
Fuel Release Fraction from Thermal Stress	The cesium and ruthenium will be held tightly by the silicon and boron in the glass, just as the sodium is held; thus, the releases of ruthenium and cesium will be the same as the particulates.
Clad or Canister Release	The behavior of the DOE HLW canister is based on the results of impact tests performed on a HLW canister (DIRS 102088-Smith and Ross 1975, pp. 27 – 44). As shown in Appendix C, the probability of the SNF canister failing from impact with an unyielding surface at between 30 to 60 mph is 2%. This failure probability increases to 20% for impacts between 60 and 90 mph, to 50% for impacts between 90 and 120 mph, and to 100% for impacts above 120 mph. The pressure inside the cask at the time of the release is based on the assumption that the canister and cask were closed at room temperature and atmospheric pressure. The fuel temperature during normal transport was assumed to be 300 °C. Thus, the pressure inside the cask at the time of cask failure by impact was assumed to be 1.91 atmospheres (13.3 psig).
Fraction of radionuclides deposited in cask inner surfaces	Same as PWR deposition fraction.
Cask Damage	Same as cask loaded with PWR fuel.
Fraction of deposited material volatilized in fire when two areas of the cask are breached	There will be no volatilization of deposited materials because they are bound to the silicon and boron.
Release fraction from cask	The HLW canister failure model is used; gas in the sealed canister provides the only driving force for release.

5.3.2.3.2 Dose Consequence Assumptions. To determine the dose consequence terms per curie of an isotope released, atmospheric dispersion was calculated to obtain the downwind airborne concentrations and the ground concentrations from cloud depletion. The assumptions made to model the airborne dispersion in RADTRAN 5 were as follows:

- National average meteorological conditions were assumed as shown in Table 5-22.
- Isotopes were grouped according to physical and chemical properties, as shown in Table 5-23.

Table 5-22. National average meteorological conditions used in RADTRAN accident analysis.

Pasquill stability class	Fraction of total meteorology	Associated wind speed (m/sec)[a]
A	0.011	1
B	0.068	2
C	0.114	3
D	0.472	4
E	0.121	2.5
F/G	0.214	1

a. From DIRS 155430 (Neuhauser, Kanipe, and Weiner 2000, p. 60); these wind speeds are not user-definable.

Table 5-23. Physical/chemical groups of radioisotopes.

Isotope	Physical/chemical group
H-3, C-14, Kr-85	Gas
Cl-36, iodine and cesium isotopes	Volatile (called "cesium")
Ru-106	Ruthenium
Co-60 in crud	Crud
Neutron activation products	Structural, (release fraction=0)
All other radioisotopes	Particulates

- Deposition velocity for all materials except gases was assumed to be 0.01 meter per second (gases were assumed not to settle out of the atmosphere). H-3 and C-14 were modeled as gases for calculating inhalation, resuspension, groundshine, and immersion doses. However, because both isotopes are taken up by vegetation, a deposition velocity of 0.01 meter per second was used for estimating the ingestion dose.

- No shielding of receptors was assumed.

- The population that would be exposed in the event of release of radioactive material was modeled by assuming that the population density in the 0.8-kilometer (0.5-mile)-wide band on either side of the route was the same population density under the entire plume, out to 80 kilometers (50 miles) from the accident.

- No cleanup, interdiction, or evacuation was assumed to occur.

- All released and dispersed radioactive material was assumed to be aerosolized and respirable.

- RADTRAN 5 standard values were used for other parameters such as breathing rate.

5.3.2.4 Use of Computer Software/Models

Isotope per-curie unit risk factors for inhalation, resuspension, groundshine, and cloudshine were calculated using the accident module of RADTRAN 5. RADTRAN 5 runs on a UNIX mainframe computer at Sandia National Laboratories and is accessed through the password-protected TRANSNET gateway at the Internet Protocol (IP) address 132.175.127.23. A secure shell terminal emulator that uses the computer as a "dumb terminal" must be used to access

TRANSNET. Instructions for obtaining a password and a secure shell are available at http://ttd.sandia.gov/risk/radtran/htm.

The database contains all the tables and queries needed to determine the accident dose risk.

5.3.2.5 Results

Severity fractions and release fractions for the fuels analyzed, in the casks and transportation modes considered, are presented in this section in approximately the same order as the fuels discussed in preceding sections. Unit risk factors for use in the database are also presented. The dose risks calculated from these estimates are presented in Section 7.5.

Section 5.3.2.5.1 presents the accident severity categories and associated release fraction for PWR and BWR SNFs. Section 5.3.2.5.2 presents the six accident severity categories for DOE SNF and HLW, GTCC, and SPAR waste. Section 5.3.2.5.3 presents the RADTRAN results and calculation of ingestion doses. Section 5.3.2.5.4 presents an example that illustrates the calculation of an accident dose risk.

The methods used to derive the accident severity categories and release fractions were presented in Section 5.3.2.2 (Methods), and the assumptions involved were presented in Section 5.3.2.3 (Assumptions). See Section 5.3.2.2.4 for the per-curie unit risk factors for inhalation, cloudshine, resuspension, immersion, and ingestion.

5.3.2.5.1 Severity and Release Fractions for PWR and BWR Fuel

5.3.2.5.1.1 Legal-weight truck and rail transportation. In DIRS 152476 (Sprung et al. 2000, Chapter 7), detailed mechanical analyses were performed on two truck cask types and two rail cask types. All SNF and HLW tables presented in this section are based on the performance of the steel-depleted uranium-steel truck cask and the steel-lead-steel rail cask, except for the Navy SNF cask, which is based on the performance of the monolithic rail cask. Figures 5-2 through 5-5 show the release fraction data for PWR and BWR fuel shipped in the representative truck and rail casks. For each mode, one figure shows the releases when the cask is loaded with PWR fuel and the other with BWR fuel. The number at the top of each cell is the case number designation used in Sprung et al. (DIRS 152476-2000, pp. 73 to 76). Below the number is the failure mode statement. The release fractions for five different material categories are shown on the next five lines. The final line is the severity fraction: the conditional probability that a cask involved in an accident will experience the failure mode represented by the impact velocity and temperature associated with the matrix cell.

Release fractions for the six severity categories that were derived from the Sprung et al. cases (DIRS 152476-Sprung et al. 2000, pp. 73 to 76) and derived from Figures 5-2 through 5-5, using Equations 5-1 and 5-2, are shown in Tables 5-24 to 5-27.

5.3.2.5.1.2 Heavy-Haul Truck Transportation. The heavy-haul analysis in the EIS is different from the analysis in DIRS 152476 (Sprung et al. 2000, pp. 8-45 to 8-47), which assumed that the accident could be characterized as the truck accident environment in which the transport speed of the vehicle would be less than 30 miles per hour, and any impact speed would be at most 60 miles per hour. The 19 truck cases were thus reduced to four fire cases, and the release fractions for these four cases were reduced by an order of magnitude from the rail cases.

Equivalent Impact onto an unyielding surface (mph)

>120	1 Seal Failure on Impact (Part) 6.0E-07 (Ru) 6.0E-07 (Cs) 2.4E-08 (Kr) 8.0E-01 (Crud) 2.0E-03 Prob 1.53E-08	11 Seal Failure on Impact (Part) 6.1E-07 (Ru) 6.1E-07 (Cs) 2.4E-08 (Kr) 8.2E-01 (Crud) 2.0E-03 Prob 1.44E-10	12 Seal Failure on Impact (Part) 6.7E-07 (Ru) 6.7E-07 (Cs) 2.7E-08 (Kr) 8.9E-01 (Crud) 2.2E-03 Prob 1.02E-12	13 Seal Failure on Impact (Part) 6.8E-07 (Ru) 6.8E-07 (Cs) 5.9E-06 (Kr) 9.1E-01 (Crud) 2.5E-03 Prob 0.00E-00	17 Failure by Shear/Puncture Seal Failure from Fire (Part) 6.8E-07 (Ru) 6.4E-06 (Cs) 5.9E-06 (Kr) 9.1E-01 (Crud) 3.3E-03 Prob 0.00E-00
90 – 120		8 Seal Failure by Fire (Part) 6.1E-07 (Ru) 6.2E-07 (Cs) 2.4E-08 (Kr) 8.9E-01 (Crud) 2.0E-03 Prob 1.13E-08	9 Seal Failure by Fire (Part) 6.7E-07 (Ru) 6.7E-07 (Cs) 2.7E-08 (Kr) 8.9E-01 (Crud) 2.2E-03 Prob 8.03E-11	10 Seal Failure by Fire (Part) 6.8E-07 (Ru) 6.8E-07 (Cs) 5.9E-06 (Kr) 9.1E-01 (Crud) 2.5E-03 Prob 0.00E-00	16 Failure by Shear/Puncture Seal Failure from Fire (Part) 6.8E-07 (Ru) 6.4E-06 (Cs) 5.9E-06 (Kr) 9.1E-01 (Crud) 3.3E-03 Prob 0.00E-00
60 – 90		5 Seal Failure by Fire (Part) 3.2E-07 (Ru) 3.2E-07 (Cs) 1.3E-08 (Kr) 4.3E-01 (Crud) 1.8E-03 Prob 4.65E-07	6 Seal Failure by Fire (Part) 3.7E-07 (Ru) 3.7E-07 (Cs) 1.5E-08 (Kr) 4.9E-01 (Crud) 2.1E-03 Prob 3.31E-09	7 Seal Failure by Fire (Part) 2.1E-06 (Ru) 2.1E-06 (Cs) 2.7E-05 (Kr) 8.5E-01 (Crud) 3.1E-03 Prob 0.00E-00	15 Failure by Shear/Puncture Seal Failure from Fire (Part) 9.0E-06 (Ru) 5.0E-05 (Cs) 5.5E-05 (Kr) 8.5E-01 (Crud) 5.9E-03 Prob 0.00E-00
30 – 60		2 Seal Failure by Fire (Part) 1.0E-07 (Ru) 1.0E-07 (Cs) 4.1E-09 (Kr) 1.4E-01 (Crud) 1.4E-03 Prob 5.88E-05	3 Seal Failure by Fire (Part) 1.3E-07 (Ru) 1.3E-07 (Cs) 5.4E-09 (Kr) 1.8E-01 (Crud) 1.8E-03 Prob 1.81E-06	4 Seal Failure by Fire (Part) 3.8E-06 (Ru) 3.8E-06 (Cs) 3.6E-05 (Kr) 8.4E-01 (Crud) 3.2E-03 Prob 7.49E-08	14 Failure by Shear/Puncture Seal Failure from Fire (Part) 1.8E-05 (Ru) 8.4E-05 (Cs) 9.6E-05 (Kr) 8.4E-01 (Crud) 6.4E-03 Prob 7.49E-11
No Impact	19 No Releases Prob 0.99993			18 Seal Failure by Fire (Part) 6.7E-08 (Ru) 6.7E-08 (Cs) 1.7E-05 (Kr) 8.4E-01 (Crud) 2.5E-03 Prob 5.86E-06	
	No Fire (300 °C)	$T_a - T_s$ (300 to 350 °C)	$T_a - T_b$ (300 to 750 °C)	A $T_a - T_f$ (300 to 1000 °C)	B $T_a - T_f$ (300 to 1000 °C)

Initial and Final Temperature Associated with Cells

a. Source: DIRS 152476 (Sprung et al. 2000)

Figure 5-2. PWR depleted uranium truck cask, temperature versus impact velocity matrix[a].

Equivalent Impact onto an unyielding surface (mph)

>120	1 Seal Failure on Impact (Part) 6.0E-07 (Ru) 6.0E-07 (Cs) 2.4E-08 (Kr) 8.0E-01 (Crud) 2.0E-03 Prob 1.53E-08	11 Seal Failure on Impact (Part) 6.1E-07 (Ru) 6.1E-07 (Cs) 2.4E-08 (Kr) 8.2E-01 (Crud) 2.0E-03 Prob 1.44E-10	12 Seal Failure on Impact (Part) 6.7E-07 (Ru) 6.7E-07 (Cs) 2.7E-08 (Kr) 8.9E-01 (Crud) 2.2E-03 Prob 1.02E-12	13 Seal Failure on Impact (Part) 6.8E-07 (Ru) 6.8E-07 (Cs) 5.9E-06 (Kr) 9.1E-01 (Crud) 2.5E-03 Prob 0.00E-00	17 Failure by Shear/Puncture Seal Failure from Fire (Part) 6.8E-07 (Ru) 6.4E-06 (Cs) 5.9E-06 (Kr) 9.1E-01 (Crud) 3.3E-03 Prob 0.00E-00
90 – 120		8 Seal Failure by Fire (Part) 6.1E-07 (Ru) 6.1E-07 (Cs) 2.4E-08 (Kr) 8.2E-01 (Crud) 2.0E-03 Prob 1.13E-08	9 Seal Failure by Fire (Part) 6.7E-07 (Ru) 6.7E-07 (Cs) 2.7E-08 (Kr) 8.9E-01 (Crud) 2.2E-03 Prob 8.03E-11	10 Seal Failure by Fire (Part) 6.8E-07 (Ru) 6.8E-07 (Cs) 5.9E-06 (Kr) 9.1E-01 (Crud) 2.5E-03 Prob 0.00E-00	16 Failure by Shear/Puncture Seal Failure from Fire (Part) 6.8E-07 (Ru) 6.4E-06 (Cs) 5.9E-06 (Kr) 9.1E-01 (Crud) 3.3E-03 Prob 0.00E-00
60 – 90		5 Seal Failure by Fire (Part) 7.3E-08 (Ru) 7.3E-08 (Cs) 2.9E-09 (Kr) 9.8E-02 (Crud) 1.8E-03 Prob 4.65E-07	6 Seal Failure by Fire (Part) 3.7E-07 (Ru) 3.7E-07 (Cs) 1.5E-08 (Kr) 4.9E-01 (Crud) 1.7E-03 Prob 3.31E-09	7 Seal Failure by Fire (Part) 4.0E-06 (Ru) 4.0E-06 (Cs) 3.7E-05 (Kr) 8.4E-01 (Crud) 3.2E-03 Prob 0.00E-00	15 Failure by Shear/Puncture Seal Failure from Fire (Part) 2.0E-05 (Ru) 8.9E-05 (Cs) 1.0E-04 (Kr) 8.4E-01 (Crud) 6.4E-03 Prob 0.00E-00
30 – 60		2 Seal Failure by Fire (Part) 4.0E-09 (Ru) 4.0E-09 (Cs) 1.6E-10 (Kr) 5.4E-03 (Crud) 1.4E-03 Prob 5.88E-05	3 Seal Failure by Fire (Part) 1.1E-08 (Ru) 1.1E-08 (Cs) 4.5E-10 (Kr) 1.5E-02 (Crud) 1.8E-03 Prob 1.81E-06	4 Seal Failure by Fire (Part) 4.9E-06 (Ru) 4.9E-06 (Cs) 4.1E-05 (Kr) 8.4E-01 (Crud) 3.1E-03 Prob 7.49E-08	14 Failure by Shear/Puncture Seal Failure from Fire (Part) 2.0E-05 (Ru) 8.9E-05 (Cs) 1.0E-04 (Kr) 8.4E-01 (Crud) 6.4E-03 Prob 7.49E-11
No Impact	19 No Releases Prob 0.99993			18 Seal Failure by Fire (Part) 6.7E-08 (Ru) 6.7E-08 (Cs) 1.7E-05 (Kr) 8.4E-01 (Crud) 2.5E-03 Prob 5.86E-06	
	No Fire (300 °C)	$T_a – T_s$ (300 to 350 °C)	$T_a - T_b$ (300 to 750 °C)	A $T_a – T_f$ (300 to 1000 °C)	B $T_a – T_f$ (300 to 1000 °C)

Initial and Final Temperature Associated with Cells

Figure 5-3. BWR depleted uranium truck cask, temperature versus impact velocity matrix.[a]

Equivalent Impact onto an unyielding surface (mph)

>120	3 Seal Failure on Impact (Part) 1.9E-05 (Ru) 1.9E-05 (Cs) 1.8E-05 (Kr) 8.0E-01 (Crud) 6.4E-02 Prob 4.49E-09	13 Seal Failure on Impact (Part) 2.0E-05 (Ru) 2.0E-05 (Cs) 1.8E-05 (Kr) 8.2E-01 (Crud) 6.5E-02 Prob 3.70E-11	14 Seal Failure on Impact (Part) 2.1E-05 (Ru) 2.1E-05 (Cs) 2.0E-05 (Kr) 8.9E-01 (Crud) 7.1E-02 Prob 1.03E-12	15 Seal Failure on Impact (Part) 2.2E-05 (Ru) 2.2E-05 (Cs) 2.2E-05 (Kr) 9.1E-01 (Crud) 7.4E-02 Prob 1.37E-13	19 Failure by Shear/Puncture Seal Failure from Fire (Part) 2.2E-05 (Ru) 2.3E-05 (Cs) 2.2E-05 (Kr) 9.1E-01 (Crud) 7.4E-02 Prob 1.37E-16
90 – 120	2 Seal Failure on Impact (Part) 1.3E-05 (Ru) 1.3E-05 (Cs) 8.6E-06 (Kr) 8.0E-01 (Crud) 4.4E-02 Prob 5.68E-07	10 Seal Failure by Impact (Part) 1.3E-05 (Ru) 1.3E-05 (Cs) 8.8E-06 (Kr) 8.2E-01 (Crud) 4.5E-02 Prob 4.68E-09	11 Seal Failure by Impact (Part) 1.5E-05 (Ru) 1.5E-05 (Cs) 9.6E-06 (Kr) 8.9E-01 (Crud) 4.9E-02 Prob 1.31E-10	12 Seal Failure by Impact (Part) 1.5E-05 (Ru) 1.5E-05 (Cs) 1.4E-05 (Kr) 9.1E-01 (Crud) 5.1E-02 Prob 1.74E-11	18 Failure by Shear/Puncture Seal Failure from Fire (Part) 1.5E-05 (Ru) 1.8E-05 (Cs) 1.4E-05 (Kr) 9.1E-01 (Crud) 5.1E-02 Prob 1.74E-14
60 – 90	1 Seal Failure on Impact (Part) 2.5E-07 (Ru) 2.5E-07 (Cs) 1.2E-08 (Kr) 4.1E-01 (Crud) 1.4E-03 Prob 8.20E-06	7 Seal Failure by Impact (Part) 2.6E-07 (Ru) 2.6E-07 (Cs) 1.3E-08 (Kr) 4.3E-01 (Crud) 1.5E-03 Prob 6.76E-08	8 Seal Failure by Impact (Part) 2.9E-07 (Ru) 2.9E-07 (Cs) 1.5E-08 (Kr) 4.9E-01 (Crud) 1.7E-03 Prob 1.88E-09	9 Seal Failure by Impact (Part) 6.8E-06 (Ru) 6.8E-06 (Cs) 2.7E-05 (Kr) 8.5E-01 (Crud) 4.5E-03 Prob 2.51E-10	17 Failure by Shear/Puncture, Seal Failure from Fire (Part) 8.9E-06 (Ru) 5.0E-05 (Cs) 5.5E-05 (Kr) 8.5E-01 (Crud) 5.4E-03 Prob 2.51E-13
30 – 60		4 Seal Failure by Fire (Part) 1.0E-07 (Ru) 1.0E-07 (Cs) 4.1E-09 (Kr) 1.4E-01 (Crud) 1.4E-03 Prob 2.96E-05	5 Seal Failure by Fire (Part) 1.3E-07 (Ru) 1.3E-07 (Cs) 5.4E-09 (Kr) 1.8E-01 (Crud) 1.8E-03 Prob 8.24E-07	6 Seal Failure by Fire (Part) 1.4E-05 (Ru) 1.4E-05 (Cs) 3.6E-05 (Kr) 8.4E-01 (Crud) 5.4E-03 Prob 1.10E-07	16 Failure by Shear/Puncture, Seal Failure from Fire (Part) 1.8E-05 (Ru) 8.4E-05 (Cs) 9.6E-05 (Kr) 8.4E-01 (Crud) 6.4E-03 Prob 4.15E-10
No Impact	21 No Release Prob 0.99996			20 Seal Failure by Fire (Part) 2.5E-07 (Ru) 2.5E-07 (Cs) 1.7E-05 (Kr) 8.4E-01 (Crud) 9.4E-03 Prob 4.91E-05	
	No Fire (300 °C)	$T_a - T_s$ (300 to 350 °C)	$T_a - T_b$ (300 to 750 °C)	A $T_a - T_f$ (300 to 1000 °C)	B $T_a - T_f$ (300 to 1000 °C)

Initial and Final Temperature Associated with Cells

a. Source: DIRS 152476 (Sprung et al. 2000, pp. 7-73 to 7-76)

Figure 5-4. PWR lead rail cask, temperature versus impact velocity cask model[a].

Equivalent Impact onto an unyielding surface (mph)					
>120	3 Seal Failure on Impact (Part) 1.9E-05 (Ru) 1.9E-05 (Cs) 1.8E-05 (Kr) 8.0E-01 (Crud) 6.4E-02 Prob 4.49E-09	13 Seal Failure on Impact (Part) 2.0E-05 (Ru) 2.0E-05 (Cs) 1.8E-05 (Kr) 8.2E-01 (Crud) 6.5E-02 Prob 3.70E-11	14 Seal Failure on Impact (Part) 2.1E-05 (Ru) 2.1E-05 (Cs) 2.0E-05 (Kr) 8.9E-01 (Crud) 7.1E-02 Prob 1.03E-12	15 Seal Failure on Impact (Part) 2.2E-05 (Ru) 2.2E-05 (Cs) 2.2E-05 (Kr) 9.1E-01 (Crud) 7.4E-02 Prob 1.37E-13	19 Failure by Shear/Puncture Seal Failure from Fire (Part) 2.2E-05 (Ru) 2.3E-05 (Cs) 2.2E-05 (Kr) 9.1E-01 (Crud) 7.4E-02 Prob 1.37E-17
90 – 120	2 Seal Failure on Impact (Part) 1.3E-05 (Ru) 1.3E-05 (Cs) 8.6E-06 (Kr) 8.0E-01 (Crud) 4.4E-02 Prob 5.68E-07	10 Seal Failure by Impact (Part) 1.3E-05 (Ru) 1.3E-05 (Cs) 8.8E-06 (Kr) 8.2E-01 (Crud) 4.5E-02 Prob 4.68E-10	11 Seal Failure by Impact (Part) 1.5E-05 (Ru) 1.5E-05 (Cs) 9.6E-06 (Kr) 8.9E-01 (Crud) 4.9E-02 Prob 1.31E-10	12 Seal Failure by Impact (Part) 1.5E-05 (Ru) 1.5E-05 (Cs) 1.4E-05 (Kr) 9.1E-01 (Crud) 5.1E-02 Prob 1.74E-11	18 Failure by Shear/Puncture Seal Failure from Fire (Part) 1.5E-05 (Ru) 1.8E-05 (Cs) 1.4E-05 (Kr) 9.1E-01 (Crud) 5.1E-02 Prob 1.74E-14
60 – 90	1 Seal Failure on Impact (Part) 5.3E-08 (Ru) 5.3E-08 (Cs) 2.7E-09 (Kr) 8.9E-02 (Crud) 8.9E-04 Prob 8.20E-06	7 Seal Failure by Impact (Part) 5.9E-08 (Ru) 5.9E-08 (Cs) 2.9E-09 (Kr) 9.8E-02 (Crud) 9.8E-04 Prob 6.76E-08	8 Seal Failure by Impact (Part) 8.3E-08 (Ru) 8.3E-08 (Cs) 4.1E-09 (Kr) 1.4E-01 (Crud) 1.4E-03 Prob 1.88E-09	9 Seal Failure by Impact (Part) 1.5E-05 (Ru) 1.5E-05 (Cs) 3.7E-05 (Kr) 8.4E-01 (Crud) 4.9E-03 Prob 2.51E-10	17 Failure by Shear/Puncture, Seal Failure from Fire (Part) 2.0E-05 (Ru) 8.9E-05 (Cs) 1.0E-04 (Kr) 8.4E-01 (Crud) 5.9E-03 Prob 2.51E-13
30 – 60		4 Seal Failure by Fire (Part) 4.0E-09 (Ru) 4.0E-09 (Cs) 1.6E-10 (Kr) 5.4E-03 (Crud) 4.5E-04 Prob 2.96E-05	5 Seal Failure by Fire (Part) 1.1E-08 (Ru) 1.1E-08 (Cs) 4.5E-10 (Kr) 1.5E-01 (Crud) 1.3E-03 Prob 8.24E-07	6 Seal Failure by Fire (Part) 1.8E-05 (Ru) 1.8E-05 (Cs) 4.1E-05 (Kr) 8.4E-01 (Crud) 5.4E-03 Prob 1.10E-07	16 Failure by Shear/Puncture, Seal Failure from Fire (Part) 2.4E-05 (Ru) 1.1E-04 (Cs) 1.2E-04 (Kr) 8.4E-01 (Crud) 6.5E-03 Prob 4.15E-10
No Impact	21 No Release Prob 0.99996			20 Seal Failure by Fire (Part) 2.5E-07 (Ru) 2.5E-07 (Cs) 1.7E-05 (Kr) 8.4E-01 (Crud) 9.4E-03 Prob 4.91E-05	
	No Fire (300 °C)	$T_a - T_s$ (300 to 350 °C)	$T_a - T_b$ (300 to 750 °C)	A $T_a - T_f$ (300 to 1000 °C)	B $T_a - T_f$ (300 to 1000 °C)

Initial and Final Temperature Associated with Cells

a. Source: DIRS 152476 (Sprung et al. 2000, pp. 7-73 to 7-76).

Figure 5-5. BWR lead rail cask, temperature versus impact velocity cask model[a].

Table 5-24. Severity and release fractions for the legal-weight truck transport of PWR fuel in the steel-depleted uranium-steel truck cask.

Severity category	Case	Severity fraction	PWR release fractions Kr	Cs	Ru	Particulates	Crud
1	19	0.99993	0.00000	0.00000	0.00000	0.00000	0.00000
2	2, 3	6.06E-05	1.36E-01	4.09E-09	1.02E-07	1.02E-07	1.36E-03
3	18	5.86E-06	8.39E-01	1.68E-05	6.71E-08	6.71E-08	2.52E-03
4	1, 5, 6, 8	4.95E-07	4.49E-01	1.35E-08	3.37E-07	3.37E-07	1.83E-03
5	4	7.49E-08	8.35E-01	3.60E-05	3.77E-06	3.77E-06	3.16E-03
6	7, 9, 10, 11, 12, 13, 14, 15, 16, 17	3.00E-10	8.40E-01	2.40E-05	2.14E-05	5.01E-06	3.17E-03

Table 5-25. Severity and release fractions for the legal-weight truck transport of BWR fuel in the steel-depleted uranium-steel truck cask.

Severity category	Case	Severity fraction	BWR release fractions Kr	Cs	Ru	Particulates	Crud
1	19	0.99993	0.00000	0.00000	0.00000	0.00000	0.00000
2	2, 3	6.06E-05	5.65E-03	1.70E-10	4.24E-09	4.24E-09	4.71E-04
3	18	5.86E-06	8.39E-01	1.68E-05	6.71E-08	6.71E-08	2.52E-03
4	1, 5, 6, 8	4.95E-07	1.36E-01	4.08E-09	1.02E-07	1.02E-07	1.27E-03
5	4	7.49E-08	8.38E-01	4.13E-05	4.88E-06	4.88E-06	3.13E-03
6	7, 9, 10, 11, 12, 13, 14, 15, 16, 17	3.00E-10	8.41E-01	3.06E-05	2.70E-05	6.55E-06	3.20E-03

Table 5-26. Severity and release fractions for rail transport of PWR fuel in the steel-lead-steel rail cask.

Severity category	Case	Severity fraction	PWR release fractions Kr	Cs	Ru	Particulates	Crud
1	21	0.99991	0.00000	0.00000	0.00000	0.00000	0.00000
2	1, 4, 5, 7, 8	3.87E-05	1.96E-01	5.87E-09	1.34E-07	1.34E-07	1.37E-03
3	20	4.91E-05	8.39E-01	1.68E-05	2.52E-07	2.52E-07	9.44E-03
4	2, 3, 10	5.77E-07	8.00E-01	8.71E-06	1.32E-05	1.32E-05	4.42E-03
5	6	1.10E-07	8.35E-01	3.60E-05	1.37E-05	1.37E-05	5.36E-03
6	9, 11, 12, 13, 14, 15, 16, 17, 18, 19	8.52E-10	8.47E-01	5.71E-05	4.63E-05	1.43E-05	1.59E-02

Table 5-27. Severity and release fractions for rail transport of BWR fuel in the steel-lead-steel rail cask.

Severity category	Case	Severity fraction	BWR release fractions Kr	Cs	Ru	Particulates	Crud
1	21	0.99991	0.00000	0.00000	0.00000	0.00000	0.00000
2	1, 4, 5, 7, 8	3.87E-05	2.35E-02	7.04E-10	1.47E-08	1.47E-08	5.59E-04
3	20	4.91E-05	8.39E-01	1.68E-05	2.52E-07	2.52E-07	9.44E-03
4	2, 3, 10	5.77E-07	8.00E-01	8.71E-06	1.32E-05	1.32E-05	4.42E-02
5	6	1.10E-07	8.37E-01	4.12E-05	1.82E-05	1.82E-05	5.43E-03
6	9, 11, 12, 13, 14, 15, 16, 17, 18, 19	8.52E-10	8.45E-01	7.30E-05	5.94E-05	1.96E-05	1.60E-02

Rather than adopt the assumptions of Sprung et al. (DIRS 152476-2000, pp.8-45 to 8-47), this assumes that the accident environment for heavy-haul truck transport is bounded by the rail analysis. A rail cask would be transported; therefore, rail cask release fractions are used.

Heavy-haul speeds are more similar to speeds used in the rail analysis than those in the truck analysis, even though the likelihood of a hard rock impact is slightly less for rail than for truck. The use of the rail conditional probabilities for a heavy-haul truck route is within the uncertainty range of the analyses. As a result, the severity and release fractions shown in Tables 5-28 and 5-29 are used for heavy-haul transportation.

Table 5-28. Severity and release fractions for the heavy-haul transport of PWR fuel in the steel-lead-steel rail cask.

Severity category	Case	Severity fraction	PWR release fractions Kr	Cs	Ru	Particulates	Crud
1	21	0.99991	0.00000	0.00000	0.00000	0.00000	0.00000
2	1, 4, 5, 7, 8	3.87E-05	1.96E-01	5.87E-09	1.34E-07	1.34E-07	1.37E-03
3	20	4.91E-05	8.39E-01	1.68E-05	2.52E-07	2.52E-07	9.44E-03
4	2, 3, 10	5.77E-07	8.00E-01	8.71E-06	1.32E-05	1.32E-05	4.42E-03
5	6	1.10E-07	8.35E-01	3.60E-05	1.37E-05	1.37E-05	5.36E-03
6	9, 11, 12, 13, 14, 15, 16, 17, 18, 19	8.52E-10	8.47E-01	5.71E-05	4.63E-05	1.43E-05	1.59E-02

Table 5-29. Severity and release fractions for the heavy-haul transport of BWR fuel in the steel-lead-steel rail cask.

Severity category	Case	Severity fraction	BWR release fractions				
			Kr	Cs	Ru	Particulates	Crud
1	21	0.99991	0.00000	0.00000	0.00000	0.00000	0.00000
2	1, 4, 5, 7, 8	3.87E-05	2.35E-02	7.04E-10	1.47E-08	1.47E-08	5.59E-04
3	20	4.91E-05	8.39E-01	1.68E-05	2.52E-07	2.52E-07	9.44E-03
4	2, 3, 10	5.77E-07	8.00E-01	8.71E-06	1.32E-05	1.32E-05	4.42E-02
5	6	1.10E-07	8.37E-01	4.12E-05	1.82E-05	1.82E-05	5.43E-03
6	9, 11, 12, 13, 14, 15, 16, 17, 18, 19	8.52E-10	8.45E-01	7.30E-05	5.94E-05	1.96E-05	1.60E-02

5.3.2.5.1.3 Barge Transportation. Only rail casks would be used for barge transport. As with heavy-haul transport, the accident environment represented by the DIRS 152476 (Sprung et al. 2000, Chapter 7) accident cases was assumed to exist during barge transport.

The truck, rail, and heavy-haul transport accident environments can be characterized as high-speed impacts with decelerations that can be hundreds of times gravitational acceleration, while the barge accident environment is characterized by very slow impacts where the deceleration affecting the cargo never exceeds the acceleration due to gravity. However, the barge environment could generate forces that are sufficient to fail a cask. If a cask is stowed among other cargo, it can be pinned and experience crush forces that can deform the cask. Similarly, slow-velocity puncture probes, because of the huge mass behind them, might penetrate a shipping cask. Sandia National Laboratories' extensive analysis of the potential behavior of casks transported on ocean-going vessels (DIRS 157395-Sprung et al. 1998, pp. 8-1 to 8-8), considered fewer cases than the 21 rail and 19 truck cases in Sprung et al. (DIRS 152476-2000, pp. 7-73 to 7-76). Therefore, release fractions for the 21 rail cases were compared to those for the 5 barge cases, and the 5 barge cases were assigned to a rail case having an equivalent set of release fractions in the rail accident severity matrix. The results of a more severe barge crush and puncture accident environments were compared with the rail impact speed environment. Once the match had been made, the barge accident severity probability was assigned to that cell. The results of this analysis are shown in Figure 5-6.

Conditional probabilities were assumed to be independent of a cask's payload contents because responses of cask structures and shield wall temperature in accidents would be determined mostly by accidental forces and external heating. The same rail release fractions for the collapsed groupings were used, with only the probabilities adjusted. Tables 5-30 and 5-31 show the data that were used to estimate the impacts from barge transport.

Accident Impact Velocity	No Fire	$T_a - T_s$	$T_a - T_b$	A $T_a - T_f$	B $T_a - T_f$
> 120	3 (R) 4.49×10^{-9}	13 (R) 3.70×10^{-11}	14 (R) 1.03×10^{-13}	15 (R) 1.37×10^{-13}	19 (R) 1.37×10^{-16}
90 – 120	2 (R) 5.68×10^{-7}	10 (R) 4.68×10^{-9}	11 (R) 1.31×10^{-10}	12 (R) 1.74×10^{-11}	18 (R) 1.74×10^{-14}
60 – 90	1 (R) 8.20×10^{-6} 2 (B) 5.0×10^{-4}	7 (R) 6.76×10^{-8}	8 (R) 1.88×10^{-9}	9 (R) 2.51×10^{-10}	17 (R) 2.51×10^{-13}
30 – 60		4 (R) 2.96×10^{-5} 1 (B) 5.0×10^{-3}	5 (R) 8.24×10^{-7}	6 (R) 1.10×10^{-7}	16 (R) 4.15×10^{-10} 4 (B) 1.3×10^{-5}
< 30	21 (R) 0.99991 5 (B) 0.994427			20 (R) 4.91×10^{-5} 3 (B) 6.0×10^{-5}	

Thermal Response

Note:
(R) = Rail
(B) = Barge

Figure 5-6. Probability distribution for severe rail (steel-lead-steel cask) and barge (steel-lead-steel cask) accidents

Table 5-30. Severity and release fraction for PWR spent fuel transported by rail or barge.

Severity category	Case	Severity fraction		PWR release fractions				
		Rail	Barge	Kr	Cs	Ru	Particulates	Crud
1	21	0.99991	0.994427	0.00000	0.00000	0.00000	0.00000	0.00000
2	1, 4, 5, 7, 8	3.87E-05	5.00E-03	1.96E-01	5.87E-09	1.34E-07	1.34E-07	1.37E-03
3	20	4.91E-05	5.00E-06	8.39E-01	1.68E-05	2.52E-07	2.52E-07	9.44E-03
4	2, 3, 10	5.77E-07	5.00E-04	8.00E-01	8.71E-06	1.32E-05	1.32E-05	4.42E-03
5	6	1.10E-07	0.00E-00	8.35E-01	3.60E-05	1.37E-05	1.37E-05	5.36E-03
6	9, 11, 12, 13, 14, 15, 16, 17, 18, 19	8.52E-10	1.30E-06	8.47E-01	5.71E-05	4.63E-05	1.43E-05	1.59E-02

Table 5-31. Severity and release fraction for BWR spent fuel transported by rail or barge.

Severity category	Case	Severity fraction		BWR release fractions				
		Rail	Barge	Kr	Cs	Ru	Particulates	Crud
1	21	0.99991	0.994427	0.00000	0.00000	0.00000	0.00000	0.00000
2	1, 4, 5, 7, 8	3.87E-05	5.00E-03	2.35E-02	7.04E-10	1.47E-08	1.47E-08	5.59E-04
3	20	4.91E-05	5.00E-06	8.39E-01	1.68E-05	2.52E-07	2.52E-07	9.44E-03
4	2, 3, 10	5.77E-07	5.00E-04	8.00E-01	8.71E-06	1.32E-05	1.32E-05	4.42E-02
5	6	1.10E-07	0.00E-00	8.37E-01	4.12E-05	1.82E-05	1.82E-05	5.43E-03
6	9, 11, 12, 13, 14, 15, 16, 17, 18, 19	8.52E-10	1.30E-06	8.45E-01	7.30E-05	5.94E-05	1.96E-05	1.60E-02

5.3.2.5.2 Severity and Release Fractions for DOE Spent Fuel. Tables 5-32 through 5-48 present the results for the DOE SNF and HLW.

5.3.2.5.2.1 DOE SNF analyzed as DOE fuel type 1.

Table 5-32. Severity and release fractions for the legal-weight truck transport of DOE SNF types 1, 2, 3, 14, and 16 in a steel-depleted uranium-steel truck cask.

Severity category	Case	Severity fraction	Release fractions				
			Kr	Cs	Ru	Particulates	Crud
1	19	0.99993	0.00000	0.00000	0.00000	0.00000	0.00000
2	2, 3	6.22E-05	5.66E-05	3.54E-07	2.29E-08	1.83E-09	5.71E-06
3	18	5.59E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
4	1, 5, 6, 8	5.16E-07	7.86E-04	1.42E-07	6.63E-08	5.80E-08	1.93E-04
5	4	6.99E-08	4.00E-03	7.87E-05	4.72E-06	3.20E-08	6.35E-05
6	7, 9, 10, 11, 12, 13, 14, 15, 16, 17	2.24E-10	7.70E-03	2.74E-04	7.57E-05	3.68E-07	1.13E-03

Table 5-33. Severity and release fractions for the rail and heavy-haul transport of DOE SNF types 1, 2, 3, 14, and 16 in the steel-lead-steel rail cask.

Severity category	Case	Severity fraction	Release fractions				
			Kr	Cs	Ru	Particulates	Crud
1	21	0.99991	0.00000	0.00000	0.00000	0.00000	0.00000
2	1, 4, 5, 7, 8	3.87E-05	2.84E-04	1.71E-06	3.91E-07	1.10E-08	2.96E-05
3	20	4.91E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
4	2, 3, 10	5.77E-07	2.13E-03	2.36E-06	3.55E-06	3.55E-06	1.18E-02
5	6	1.10E-07	4.00E-03	7.87E-05	1.77E-05	9.68E-08	1.61E-04
6	9, 11, 12, 13, 14, 15, 16, 17, 18, 19	8.52E-10	4.68E-02	9.63E-04	2.47E-04	2.73E-06	7.17E-03

5.3.2.5.2.2 DOE SNF Modeled as Failed Fuel

Table 5-34. Severity and release fractions for DOE SNF types 5 and 10 in the steel-depleted uranium-steel legal-weight truck cask

Severity category	Case	Severity fraction	Failed Fuel Release fractions				
			Kr	Cs	Ru	Particulates	Crud
1	19	0.99993	0.00000	0.00000	0.00000	0.00000	0.00000
2	2, 3	6.22E-05	2.16E-05	6.47E-11	1.62E-09	1.62E-09	5.39E-06
3	18	5.59E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
4	1, 5, 6, 8	5.16E-07	7.72E-04	2.32E-09	5.79E-08	5.79E-08	1.93E-04
5	4	6.99E-08	4.00E-03	3.14E-07	3.20E-08	3.20E-08	6.35E-05
6	7, 9, 10, 11, 12, 13, 14, 15, 16, 17	2.24E-10	6.02E-03	2.80E-07	5.16E-07	3.58E-07	1.12E-03

Table 5-35. Severity and release fractions for the rail and heavy-haul transport of DOE SNF types 5 and 10 in the steel-lead-steel rail cask.

Severity category	Case	Severity fraction	Failed Fuel Release fractions				
			Kr	Cs	Ru	particulates	Crud
1	21	0.99991	0.00000	0.00000	0.00000	0.00000	0.00000
2	1, 4, 5, 7, 8	3.87E-05	1.15E-04	3.44E-10	7.15E-09	7.15E-09	2.38E-05
3	20	4.91E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
4	2, 3, 10	5.77E-07	2.13E-03	2.36E-06	3.55E-06	3.55E-06	1.18E-02
5	6	1.10E-07	4.00E-03	3.14E-07	9.68E-08	9.68E-08	1.61E-04
6	9, 11, 12, 13, 14, 15, 16, 17, 18, 19	8.52E-10	1.67E-02	2.68E-06	2.29E-06	2.04E-06	6.15E-03

Table 5-36. Severity and release fractions for the legal-weight truck transport of GTCC and SPAR wastes in the steel-depleted uranium-steel truck cask.

Severity category	Case	Severity fraction	Release fractions				
			Kr	Cs	Ru	Particulates	Crud
1	19	0.99993	0.00000	0.00000	0.00000	0.00000	0.00000
2	2, 3	6.22E-05	2.16E-05	6.47E-11	1.62E-09	1.62E-09	5.39E-06
3	18	5.59E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
4	1, 5, 6, 8	5.16E-07	7.72E-04	2.32E-09	5.79E-08	5.79E-08	1.93E-04
5	4	6.99E-08	4.00E-03	3.14E-07	3.20E-08	3.20E-08	6.35E-05
6	7, 9, 10, 11, 12, 13, 14, 15, 16, 17	2.24E-10	6.02E-03	2.80E-07	5.16E-07	3.58E-07	1.12E-03

Table 5-37. Severity and release fractions for the rail and heavy-haul transport of GTCC and SPAR wastes in the steel-lead-steel rail cask.

Severity category	Case	Severity fraction	Release fractions				
			Kr	Cs	Ru	Particulates	Crud
1	21	0.99991	0.00000	0.00000	0.00000	0.00000	0.00000
2	1, 4, 5, 7, 8	3.87E-05	1.15E-04	3.44E-10	7.15E-09	7.15E-09	2.38E-05
3	20	4.91E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
4	2, 3, 10	5.77E-07	2.13E-03	2.36E-06	3.55E-06	3.55E-06	1.18E-02
5	6	1.10E-07	4.00E-03	3.14E-07	9.68E-08	9.68E-08	1.61E-04
6	9, 11, 12, 13, 14, 15, 16, 17, 18, 19	8.52E-10	1.67E-02	2.68E-06	2.29E-06	2.04E-06	6.15E-03

5.3.2.5.2.3 Aluminide and Silicide Fuels

Table 5-38. Severity and release fractions for the legal-weight truck transport of DOE SNF types 6 and 7 in the steel-depleted uranium-steel truck cask

Severity category	Case	Severity fraction	Aluminum-Clad Metallic Uranium and Uranium Alloy Release fractions				
			Kr	Cs	Ru	Particulates	Crud
1	19	0.99993	0.00000	0.00000	0.00000	0.00000	0.00000
2	2, 3	6.22E-05	5.66E-05	1.77E-05	1.83E-09	1.83E-09	5.71E-06
3	18	5.59E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
4	1, 5, 6, 8	5.16E-07	7.86E-04	6.99E-06	5.80E-08	5.80E-08	1.93E-04
5	4	6.99E-08	4.00E-03	3.53E-03	3.20E-08	3.20E-08	6.35E-05
6	7, 9, 10, 11, 12, 13, 14, 15, 16, 17	2.24E-10	7.70E-03	2.48E-03	3.68E-07	3.68E-07	1.13E-03

Table 5-39. Severity and release fractions for the rail and heavy-haul transport of DOE SNF types 6 and 7 in the steel-lead-steel rail cask.

Severity category	Case	Severity fraction	Aluminum-Clad Metallic Uranium and Uranium Alloy Release fractions				
			Kr	Cs	Ru	Particulates	Crud
1	21	0.99991	0.00000	0.00000	0.00000	0.00000	0.00000
2	1, 4, 5, 7, 8	3.87E-05	2.84E-04	8.53E-05	1.10E-08	1.10E-08	4.11E-05
3	20	4.91E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
4	2, 3, 10	5.77E-07	2.13E-03	2.36E-06	3.55E-06	3.55E-06	1.18E-02
5	6	1.10E-07	4.00E-03	3.53E-03	9.68E-08	9.68E-08	4.26E-04
6	9, 11, 12, 13, 14, 15, 16, 17, 18, 19	8.52E-10	4.68E-02	2.92E-02	2.73E-06	2.73E-06	1.03E-02

5.3.2.5.2.4 High-temperature Gas-cooled Reactor Fuel

Table 5-40. Severity and release fractions for the legal-weight truck transport of DOE SNF type 8 (HTGR) in the steel-depleted uranium-steel truck cask

Severity category	Case	Severity fraction	HTGR Release fractions				
			Kr	Cs	Ru	Particulates	Crud
1	19	0.99993	0.00000	0.00000	0.00000	0.00000	0.00000
2	2, 3	6.22E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
3	18	5.59E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
4	1, 5, 6, 8	5.16E-07	7.50E-04	5.63E-10	5.63E-10	5.63E-10	0.00E+00
5	4	6.99E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
6	7, 9, 10, 11, 12, 13, 14, 15, 16, 17	2.24E-10	3.52E-03	2.72E-09	2.64E-09	2.64E-09	0.00E+00

Acronyms: HTGR = high temperature gas-cooled reactor; Kr = krypton; Cs = cesium; Ru = ruthenium

Table 5-41. Severity and release fractions for the rail and heavy-haul transport of DOE SNF type 8 (HTGR) in the steel-lead-steel rail cask.

Severity category	Case	Severity fraction	HTGR Release fractions				
			Kr	Cs	Ru	Particulates	Crud
1	21	0.99991	0.00000	0.00000	0.00000	0.00000	0.00000
2	1, 4, 5, 7, 8	3.87E-05	1.02E-04	6.12E-11	6.12E-11	6.12E-11	0.00E+00
3	20	4.91E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
4	2, 3, 10	5.77E-07	4.77E-03	7.89E-08	7.89E-08	7.89E-08	0.00E+00
5	6	1.10E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
6	9, 11, 12, 13, 14, 15, 16, 17, 18, 19	8.52E-10	1.70E-03	2.84E-08	2.62E-08	2.62E-08	0.00E+00

Acronyms: HTGR = high temperature gas-cooled reactor; Kr = krypton; Cs = cesium; Ru = ruthenium

Table 5-42. Severity and release fractions for the legal-weight truck transport of DOE SNF type 9 (low-integrity HTGR) in the steel-depleted uranium-steel truck cask.

Severity category	Case	Severity fraction	Low-Integrity HTGR Release fractions				
			Kr	Cs	Ru	Particulates	Crud
1	19	0.99993	0.00000	0.00000	0.00000	0.00000	0.00000
2	2, 3	6.22E-05	5.19E-01	3.89E-07	3.89E-07	3.89E-07	0.00E+00
3	18	5.59E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E +00
4	1, 5, 6, 8	5.16E-07	5.17E-01	3.88E-07	3.88E-07	3.88E-07	0.00E+00
5	4	6.99E-08	7.64E-01	6.32E-06	5.73E-07	5.73E-07	0.00E+00
6	7, 9, 10, 11, 12, 13, 14, 15, 16, 17	2.24E-10	6.00E-01	2.33E-06	2.24E-06	4.50E-07	0.00E+00

Acronyms: HTGR = high temperature gas-cooled reactor; Kr = krypton; Cs = cesium; Ru = ruthenium

Table 5-43. Severity and release fractions for the rail and heavy-haul transport of DOE SNF type 9 (low-integrity HTGR) in the steel-lead-steel rail cask.

Severity category	Case	Severity fraction	Low-Integrity HTGR Release fractions				
			Kr	Cs	Ru	Particulates	Crud
1	21	0.99991	0.00000	0.00000	0.00000	0.00000	0.00000
2	1, 4, 5, 7, 8	3.87E-05	5.14E-01	3.70E-07	3.70E-07	3.70E-07	0.00E+00
3	20	4.91E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
4	2, 3, 10	5.77E-07	4.77E-01	7.89E-06	7.89E-06	7.89E-06	0.00E+00
5	6	1.10E-07	7.64E-01	6.32E-06	5.73E-07	5.73E-07	0.00E+00
6	9, 11, 12, 13, 14, 15, 16, 17, 18, 19	8.52E-10	7.45E-01	7.57E-06	5.82E-06	3.02E-06	0.00E+00

Acronyms: HTGR = high temperature gas-cooled reactor; Kr = krypton; Cs = cesium; Ru = ruthenium

5.3.2.5.2.5 TRIGA Fuel

Table 5-44. Severity and release fractions for the legal-weight truck transport of DOE SNF type 13 (TRIGA) in the steel-depleted uranium-steel truck cask.

Severity category	Case	Severity fraction	TRIGA Fuel Release fractions				
			Kr	Cs	Ru	Particulates	Crud
1	19	0.99993	0.00000	0.00000	0.00000	0.00000	0.00000
2	2, 3	6.22E-05	2.16E-05	6.47E-09	1.62E-07	1.62E-07	5.39E-06
3	18	5.59E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
4	1, 5, 6, 8	5.16E-07	7.92E-04	2.32E-07	5.79E-06	5.79E-06	1.93E-04
5	4	6.99E-08	1.97E-02	1.97E-02	2.51E-05	1.61E-06	2.27E-04
6	7, 9, 10, 11, 12, 13, 14, 15, 16, 17	2.24E-10	1.33E-02	9.11E-03	4.04E-04	3.22E-05	1.37E-03

Table 5-45. Severity and release fractions for the rail and heavy-haul transport of DOE SNF Category 13 (TRIGA) in the steel-lead-steel rail cask.

Severity category	Case	Severity fraction	TRIGA Fuel Release fractions				
			Kr	Cs	Ru	Particulates	Crud
1	21	0.99991	0.00000	0.00000	0.00000	0.00000	0.00000
2	1, 4, 5, 7, 8	3.87E-05	1.15E-04	3.44E-08	7.15E-07	7.15E-07	2.38E-05
3	20	4.91E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
4	2, 3, 10	5.77E-07	2.13E-03	2.36E-04	3.55E-04	3.55E-04	1.18E-02
5	6	1.10E-07	1.97E-02	1.97E-02	8.99E-05	1.93E-06	7.15E-04
6	9, 11, 12, 13, 14, 15, 16, 17, 18, 19	8.52E-10	7.98E-02	7.91E-02	5.43E-04	1.76E-04	8.58E-03

5.3.2.5.2.6 Naval SNF. The data for the Naval SNF table was developed by the Naval Reactor Project Office. The data were taken from their report and inserted in this document for completeness.

Table 5-46. Severity and release fractions for the rail and heavy-haul transport of DOE SNF type 15 (naval spent fuel) in the monolithic steel rail cask.

Severity category	Severity fraction	Naval SNF Release fractions				
		Kr	Cs	Ru	Particulates	Crud
1	0.99996	0.00000	0.00000	0.00000	0.00000	0.00000
2	4.02E-05	1.52E-02	4.55E-09	9.10E-09	9.10E-09	1.37E-03
3	6.32E-06	8.39E-02	1.68E-06	2.52E-08	2.52E-08	9.44E-03
4	1.22E-07	8.00E-02	8.98E-07	1.34E-06	1.34E-06	4.47E-02
5	1.51E-08	9.44E-02	4.00E-06	1.80E-06	1.80E-06	5.36E-03
6	1.66E-10	9.04E-02	5.49E-06	4.67E-06	1.93E-06	2.86E-02

5.3.2.5.2.7 HLW. The waste type in this category is vitrified HLW from the treatment of tank farm wastes generated from the processing of spent fuel to recover plutonium for defense purposes. The data for these waste types are presented in Tables 5-47 and 5-48.

Table 5-47. Severity and release fractions for the legal-weight truck transport of HLW in the steel-depleted uranium-steel truck cask.

Severity category	Case	Severity fraction	HLW Fuel Release fractions				
			Kr	Cs	Ru	Particulates	Crud
1	19	0.99993	0.00000	0.00000	0.00000	0.00000	0.00000
2	2, 3	6.22E-05	0.00E+00	3.35E-08	3.35E-08	3.35E-08	0.00E+00
3	18	5.59E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
4	1, 5, 6, 8	5.16E-07	0.00E+00	2.37E-07	2.37E-07	2.37E-07	0.00E+00
5	4	6.99E-08	0.00E+00	9.29E-08	9.29E-08	9.29E-08	0.00E+00
6	7, 9, 10, 11, 12, 13, 14, 15, 16, 17	2.24E-10	0.00E+00	6.56E-07	6.56E-07	2.98E-07	0.00E+00

Table 5-48. Severity and release fractions for the rail and heavy-haul transport of HLW the steel-lead-steel rail cask.

Severity category	Case	Severity fraction	HLW Fuel Release fractions				
			Kr	Cs	Ru	Particulates	Crud
1	21	0.99991	0.00000	0.00000	0.00000	0.00000	0.00000
2	1, 4, 5, 7, 8	3.87E-05	0.00E+00	6.22E-08	6.22E-08	6.22E-08	0.00E+00
3	20	4.91E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
4	2, 3, 10	5.77E-07	0.00E+00	7.89E-06	7.89E-06	7.89E-06	0.00E+00
5	6	1.10E-07	0.00E+00	9.29E-08	9.29E-08	9.29E-08	0.00E+00
6	9, 11, 12, 13, 14, 15, 16, 17, 18, 19	8.52E-10	0.00E+00	2.74E-06	2.74E-06	2.74E-06	0.00E+00

5.3.2.5.3 RADTRAN Results and Calculation of Ingestion Dose. RADTRAN 5 input and output files are in Attachment 532B on the compact disk included with this calculation package. Table 5-49 shows the per-curie dose unit risk factors calculated for each isotope. These unit risk factors include the conditional severity probabilities and the release fractions.

Table 5-49 Per-curie unit risk factors for isotopes in all inventories considered[a]. (1 of 2)

Isotope	Ingestion	Inhalation	Immersion	Resuspension	Groundshine	Notes
H3	3.03E+01	1.09E-05	6.31E-10	0.00E+00	0.00E+00	
C14	9.87E+02	4.01E-06	4.29E-10	0.00E+00	0.00E+00	
CL36	1.43E+03	4.20E-04	4.80E-09	1.92E-03	5.91E-04	
MN54	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	Structural
FE55	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	Structural
FE59	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	Structural
MN54	1.31E+03	1.29E-04	8.79E-06	2.70E-04	3.39E-02	Particulate
FE55GTC	2.87E+02	2.57E-05	0.00E+00	8.55E-05	0.00E+00	Particulate
FE59GTC	3.17E+03	2.34E-04	1.29E-05	1.16E-04	8.35E-03	Particulate
CO58	1.41E+03	2.09E-04	1.02E-05	1.55E-04	1.12E-02	
CO60	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	Structural
NI59	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	Structural
NI63	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	Structural
CO60Na	4.85E+03	4.20E-03	2.71E-05	1.61E-02	4.05E-01	Particulate
NI59N	9.92E+01	1.76E-05	0.00E+00	8.05E-05	0.00E+00	Particulate
NI63N	2.73E+02	4.42E-05	0.00E+00	1.99E-04	0.00E+00	Particulate
CO60Cb	4.85E+03	4.20E-03	2.71E-05	1.61E-02	4.05E-01	Crud
SE79	4.11E+03	1.89E-04	6.52E-11	8.63E-04	1.82E-05	
KR85	0.00E+00	0.00E+00	2.28E-07	0.00E+00	0.00E+00	
SR90	6.74E+04	4.59E-03	1.62E-09	2.02E-02	1.54E-04	
Y90	5.09E+03	1.62E-04	4.09E-08	7.14E-04	2.89E-03	
ZR93	7.84E+02	1.60E-03	0.00E+00	7.30E-03	0.00E+00	
NB93M	2.47E+02	5.61E-04	9.54E-10	2.38E-03	3.36E-04	
NB94	3.38E+03	7.95E-03	1.66E-05	3.63E-02	1.34E+00	
TC99	6.91E+02	1.60E-04	3.49E-10	7.30E-04	6.85E-05	
RU106	1.29E+04	9.16E-03	2.24E-06	2.09E-02	1.00E-02	Plus progeny
RH106	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
RH102	4.93E+03	2.30E-03	2.24E-05	7.80E-03	2.22E-01	
PD107	7.07E+01	2.46E-04	0.00E+00	1.12E-03	0.00E+00	
CD113M	7.61E+04	7.68E-03	1.50E-09	3.26E-02	9.41E-05	
SN126	9.22E+03	1.91E-03	4.54E-07	8.72E-03	4.81E-02	
SB125	1.33E+03	4.09E-05	4.35E-06	1.37E-04	4.38E-02	
I129	1.31E+05	3.34E-03	8.20E-08	1.53E-02	2.27E-02	
CS134	3.46E+04	8.89E-04	1.63E-05	2.73E-03	1.24E-01	
CS135	3.34E+03	8.74E-05	1.22E-10	3.99E-04	2.92E-05	
CS137	2.36E+04	6.12E-04	6.23E-06	2.70E-03	3.23E-01	Plus progeny
BA137M	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
PM147	4.95E+02	7.53E-04	1.49E-10	2.48E-03	3.37E-06	
SM151	1.84E+02	5.76E-04	7.80E-12	2.60E-03	3.74E-06	
EU154	4.52E+03	5.49E-03	1.32E-05	2.25E-02	3.10E-01	
EU155	7.24E+02	7.95E-04	5.36E-07	3.01E-03	9.72E-03	

Table 5-49 Per-curie unit risk factors for isotopes in all inventories considered[a]. (2 of 2)

Isotope	Ingestion	Inhalation	Immersion	Resuspension	Groundshine	Notes
PB210	2.54E+06	2.61E-01	1.22E-08	1.14E+00	1.19E-03	
PO218	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
FR221	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
RA226	6.26E+05	1.65E-01	6.81E-08	7.52E-01	5.61E-03	
RA228	6.79E+05	9.16E-02	0.00E+00	3.55E-01	0.00E+00	
AC227	6.65E+06	2.48E+01	1.25E-09	1.08E+02	7.45E-05	
AC228	1.02E+03	2.40E-03	1.03E-05	7.63E-06	4.82E-05	
TH229	1.67E+06	3.32E+01	8.26E-07	1.52E+02	7.49E-02	
TH230	2.59E+05	5.03E+00	3.75E-09	2.30E+01	6.60E-04	
TH232	1.29E+06	2.21E+01	1.88E-09	1.00E+02	4.84E-04	
PA231	5.00E+06	1.65E+01	3.70E-07	7.52E+01	3.57E-02	
U232	3.27E+04	1.27E+01	3.05E-09	5.69E+01	7.21E-04	
U233	1.25E+04	2.59E+00	3.51E-09	1.18E+01	6.30E-04	
U234	1.24E+04	2.53E+00	1.64E-09	1.16E+01	6.57E-04	
U235	1.26E+04	2.36E+00	1.55E-06	1.08E+01	1.30E-01	
U236	1.17E+04	2.40E+00	1.08E-09	1.10E+01	5.72E-04	
U238	1.12E+04	2.27E+00	7.33E-10	1.03E+01	4.84E-04	
NP237	2.10E+06	1.04E+01	2.22E-07	4.73E+01	2.52E-02	
PU238	2.34E+04	5.53E+00	1.05E-09	2.49E+01	6.20E-04	
PU239	2.45E+04	5.91E+00	9.13E-10	2.70E+01	3.22E-04	
PU240	2.45E+04	5.91E+00	1.02E-09	2.70E+01	7.05E-04	
PU241	3.62E+02	9.52E-02	1.56E-11	4.06E-01	7.18E-07	
PU242	2.33E+04	5.63E+00	8.61E-10	2.57E+01	5.86E-04	
AM241	1.72E+06	8.52E+00	1.76E-07	3.88E+01	2.33E-02	
AM242	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
AM242M	1.66E+06	8.18E+00	1.40E-07	3.71E+01	1.49E-02	Plus progeny
AM243	1.71E+06	8.45E+00	4.70E-07	3.86E+01	4.69E-02	
CM242	5.42E+04	3.32E-01	1.23E-09	4.67E-01	2.37E-05	
CM243	1.19E+06	5.89E+00	1.27E-06	2.60E+01	6.74E-02	
CM244	9.54E+05	4.76E+00	1.06E-09	2.06E+01	3.77E-04	
CM245	1.77E+06	8.74E+00	8.55E-07	3.99E+01	7.63E-02	
CM246	1.75E+06	8.66E+00	9.60E-10	3.95E+01	6.88E-04	
CM247	1.62E+06	7.95E+00	3.23E-06	3.63E+01	2.73E-01	
CM248	6.44E+06	3.17E+01	7.27E-10	1.45E+02	5.28E-04	
CF252	5.13E+05	3.01E+00	1.09E-09	9.95E+00	7.16E-05	

a. The units are rem per curie of inventory.
b. The suffix N on an isotope name denotes nonstructural; in this case, the isotope is treated like a particulate.
c. The suffix C on an isotope name denotes CRUD.

Per-curie unit risk factors were calculated off-line using an Excel spreadsheet and the ground deposition values from RADTRAN 5. The total microcuries deposited (per curie of inventory) is 473,000 (or 0.473 curies). Each isotope is then multiplied by this number and by the ingestion dose conversion factor to provide an ingestion unit risk factor, as shown in Table 5-50.

Table 5-50. Ingestion unit risk factors per curie of inventory for each isotope.

Isotope	Ingestion dose conversion factor (rem per curie ingested)	Ingestion URF	Isotope	Ingestion dose conversion factor (rem per curie ingested)	Ingestion URF
H-3	6.40E+01	3.03E+01			
C-14	2.09E+03	9.87E+02	Ra-226	1.32E+06	6.26E+05
Cl-36	3.03E+03	1.43E+03	Ra-228	1.44E+06	6.79E+05
Cr-51	1.45E+02	6.88E+01	Ac-225	1.11E+05	5.25E+04
Mn-54	2.77E+03	1.31E+03	Ac-227	1.41E+07	6.65E+06
Fe-55	6.07E+02	2.87E+02	Ac-228	2.16E+03	1.02E+03
Fe-59	6.70E+03	3.17E+03	Th-229	3.53E+06	1.67E+06
Co-58	2.99E+03	1.41E+03	Th-230	5.48E+05	2.59E+05
Co-60	1.02E+04	4.85E+03	Th-232	2.73E+06	1.29E+06
Ni-59	2.10E+02	9.92E+01	Pa-231	1.06E+07	5.00E+06
Ni-63	5.77E+02	2.73E+02	U-232	6.92E+04	3.27E+04
Se-79	8.70E+03	4.11E+03	U-233	2.65E+04	1.25E+04
Sr-90	1.53E+05	7.24E+04	U-234	2.61E+04	1.24E+04
Y-90	1.08E+04	5.09E+03	U-235	2.67E+04	1.26E+04
Zr-93	1.66E+03	7.84E+02	U-236	2.47E+04	1.17E+04
Nb-93m	5.22E+02	2.47E+02	U-238	2.38E+04	1.12E+04
Nb-94	7.14E+03	3.38E+03	Np-237	4.44E+06	2.10E+06
Nb-95	2.57E+03	1.22E+03	Pu-236	3.00E+04	1.42E+04
Tc-99	1.46E+03	6.91E+02	Pu-238	4.96E+04	2.34E+04
Ru-106	2.74E+04	1.29E+04	Pu-239	5.18E+04	2.45E+04
Rh-102	1.04E+04	4.93E+03	Pu-240	5.18E+04	2.45E+04
Pd-107	1.49E+02	7.07E+01	Pu-241	7.66E+02	3.62E+02
Cd-113m	1.61E+05	7.61E+04	Pu-242	4.92E+04	2.33E+04
Sn-119m	1.39E+03	6.58E+02	Pu-244	5.85E+04	2.76E+04
Sn-126	1.95E+04	9.22E+03	Am-241	3.64E+06	1.72E+06
Sb-126m	9.36E+01	4.43E+01	Am-242m	3.52E+06	1.66E+06
Sb-126	1.02E+04	4.83E+03	Am-242	1.41E+03	6.67E+02
Sb-125	2.81E+03	1.33E+03	Am-243	3.62E+06	1.71E+06
I-129	2.76E+05	1.31E+05	Cm-242	1.15E+05	5.42E+04
Cs-134	7.33E+04	3.46E+04	Cm-243	2.51E+06	1.19E+06
Cs-135	7.07E+03	3.34E+03	Cm-244	2.02E+06	9.54E+05
Cs-137	5.00E+04	2.36E+04	Cm-245	3.74E+06	1.77E+06
Ce-144	2.10E+04	9.94E+03	Cm-246	3.70E+06	1.75E+06
Pm-147	1.05E+03	4.95E+02	Cm-247	3.42E+06	1.62E+06
Sm-151	3.89E+02	1.84E+02	Cm-248	1.36E+07	6.44E+06
Pb-210	5.37E+06	2.54E+06	Cf-252	1.08E+06	5.13E+05

5.3.2.5.4 An Example. The calculation of accident dose risk may be illustrated by the example of the shipment of Oyster Creek BWR spent fuel through Nebraska for the Proposed Action. The transportation mode is by highway, the cask is a GA9 truck cask, and the origin, which determines the route to the repository, is Oyster Creek. Rural, urban, and suburban population densities and route segment lengths along the route through Nebraska for these shipments are also specified. The steps in the calculation (not necessarily in this order in the database) are as follows:

1. Each isotope unit risk factor is multiplied by the severity fraction (conditional accident severity probability) for the GA9 truck cask and the appropriate release fraction for the physical/chemical group the isotope belongs to.

2. The severity fraction*release fraction products in Step 1 are summed.

3. The sum for each isotope from Step 2 is multiplied by the curies of that isotope in one BWR SNF assembly (the BWR SNF inventory).

4. The result from Step 3 is multiplied by the number of assemblies carried by the GA9 truck cask in one shipment.

5. The result from Step 4 is multiplied by the total number of shipments from Oyster Creek.

6. The rural population density in Nebraska is multiplied by the length (in kilometers) of the rural part of the highway route, through Nebraska, from Oyster Creek to the repository.

7. The suburban and urban population densities are multiplied by the suburban and urban route segments, respectively.

8. The products in Step 6 are added, and the sum multiplied by the Nebraska truck accident rate.

9. The result from Step 5 is multiplied by the result from Step 7 to give the (24-year) accident dose risk from Oyster Creek BWR SNF shipments through Nebraska.

Results of the accident calculations are presented and discussed in Section 7.5 of this calculation package.

5.3.2.6 Loss-of-Shielding Accidents

For the Yucca Mountain EIS, DOE estimated the overall dose risk of transportation accidents by combining all potential radiological impacts of accidents. Included are impacts resulting from:

- release of radioactive materials from casks (see analysis in previous section);
- loss of cask shielding combined with time to recover a damaged cask; and
- no loss of shielding and no release of radioactive materials but immobilized shipments awaiting recovery from an accident

In addition, DOE estimated doses to maximally exposed individuals for maximum reasonably foreseeable accidents (see previous section) and for loss of shielding accidents. For the mostly rail scenario, both national and Nevada impacts were estimated for 10 different sets of routings - one for each of the 10 Nevada implementing transportation alternatives.

This section describes the methods assumptions, and data used to estimate impacts to populations and maximally exposed individuals (first responders) that would result from:

- loss of cask shielding in severe accidents and associated time to recover the cask and
- interruptions of normal transit caused by accidents but where a cask's radiation shield has not been damaged.

5.3.2.6.1 Introduction

As discussed previously, more than 99.99 percent of transportation accidents would not lead to a release of radioactive materials. Nonetheless, these non-release accidents, most of which would not damage the transportation cask, as well as accidents that involved release of radioactive material could also lead to radiological health and safety consequences for the general public and for first responders caused by radiation from the casks. For the majority of accidents where a cask's shielding and containment was not damaged, low-level radiation from the cask combined with time required to recover and restart the shipment would result in increased radiological expose to the nearby public and to first responder personnel. For a small fraction of accidents where high impact forces caused displacement of lead shielding in a steel-lead-steel cask (in addition to releases of radioactive material from the cask) levels of radiation external to the cask could be elevated. In these cases both the public and first responders would be exposed to the higher radiation levels.

This section includes the methods (Section 5.3.2.6.2), assumptions (Section 5.3.2.6.3), software used (Section 5.3.2.6.4), and calculation results (Section 5.3.2.6.5) for the potential loss-of-shielding transportation accident analysis.

5.3.2.6.2 Method of Analysis

The analysis used two kinds of data to estimate the dose rate external to a cask following an accident: (1) the maximum dose rate permitted by DOT regulations external to an undamaged cask (see 49 CFR 173.441), and (2) external dose rates presented in Sprung et al. (DIRS 152476-2000, Section 8.12) for casks containing spent nuclear fuel and having displaced gamma ray shields. The analysis used data from Sprung et al. (DIRS 152476-2000, Section 8.12) to analyze radiological impacts for accidents where shielding displacement could occur. For accidents where shielding would not be displaced, the analysis assumed the dose rate external to a cask would be the maximum allowed by regulations for normal transportation.

The analysis assumed that depleted uranium shielding in legal-weight truck casks would not be displaced in accidents, because it would not slump under impact forces and could not be melted by the heat of fire in transportation accidents. In addition, based on data presented by Sprung et al. (DIRS 152476-2000, Table 8.12) the analysis assumed shielding would not be lost or displaced for lead shielded rail casks in 99.99 percent of accidents where effective impact speeds would be less than 48 km/hr (30 mph) and fire durations would be less than 30 minutes.

DOE used the RADTRAN 5 computer code (DIRS 155430-Neuhauser et al. 2000, all) to calculate unit risk factors for dose risk to the public for accidents where shielding was not lost but increased exposure to the public would occur and for accidents where shielding loss occurred. The unit risk factors were input to the transportation impacts analysis database (see Appendix A) where they were used to estimate the dose risk to the public that could result from exposure to radiation from casks during and following accidents. The transportation analysis database solved Equation (5-13) to estimate this dose risk .

Equation 5-13 is used to estimte the dose risk from accidents in which vehicles could be immobilized, including accidents involving potential loss of shielding.

$$D_{LOS} = NSHIP*\Sigma_L(PD_L*ACC_L*DIST_L)*\ \Sigma_j(CP_j*\ URF_{LOS,j}) \qquad \text{Eq. (5-13)}$$

where

$NSHIP$ = total number of shipments
PD_L = population density on the Lth route segment
ACC_L = the accident rate on the Lth route segment
$DIST_L$ = length of the Lth route segment
CP_j = conditional probability of the jth loss-of-shielding accident scenario (severity fraction)
$URF_{LOS,j}$ = unit risk factor for the jth loss-of-shielding accident scenario

The unit risk factor s to estimate loss of shielding are calculated using RADTRAN. The unit risk factor equation is:

$$URF_{LOS,j} = K * DR_j * T * P * f(r, a) \qquad \text{Eq. (5-14)}$$

where

K = the appropriate conversion factor (embedded in RADTRAN)
DR_j = the dose rate for the jth accident scenario (shown in Table 5-52)
T = time (hours) that the vehicle is stopped (exposure time)
P = population density
f(r,a) = a function of the distance from the stopped vehicle to the populated area; the calculation of this function is embedded in RADTRAN (reference to RADTRAN page)

In addition to unit risk factors, the analysis used the following:

- Accidents per vehicle kilometer for each state for each mode of transportation (103455, Saricks and Tompkins 1999, Tables 4 and 6);
- Rural, urban, and suburban population densities estimated for each route in each state (see Section 3.0);
- Distances for each route in each population zone (rural, suburban, and urban) in each state (see Section 3.0);
- Number of shipments for each route and mode of transportation from each generator site for the Proposed Action and for Inventory Modules 1 and 2 (see Section 2.0);

The RADTRAN 5 computer program was also used to estimate the dose to a hypothetical first responder for a maximum reasonably foreseeable loss of shielding accident and for accidents where shielding would not be lost but time would be required for accident recovery. The dose to the maximally exposed individual was calculated in RADTRAN 5 using the following general equation:

$$D_{MEI} = NSHIP * \Sigma_L(ACC_L * DIST_L) * \Sigma_j(CP_j * URF_{MEI,j}) \qquad \text{Eq. (5-15)}$$

and

$$URF_{MEI,j} = K * DR_j * T_{MEI} * P_{MEI} * f_{MEI}(r, a) \qquad \text{Eq. (5-16)}$$

The subscript "MEI" in Equation 5-16 indicates that these parameters are different, or are calculated differently by RADTRAN, from the corresponding parameters in Equation 5-14.

5.3.2.6.3 Assumptions

This section includes assumptions for accidents in which shielding is not lost but the vehicle is immobilized, and for accidents in which shielding is lost. The vehicle involved in the accident would be immobilized.

5.3.2.6.3.1 Accidents in which shielding is not lost but the vehicle is immobilized.

DOE used the following assumptions and data to analyze the impacts of accidents where shielding would not be lost (and radioactive materials would not be released from a cask):

- The conditional probability of this accident scenario was assumed to be 0.9999 (99.99 percent);
- The dose rate at 1 meter from an undamaged shipping cask in such transportation accidents would be 14 millirem per hour (TI = 14) (this is approximately equal to the dose rate 1 meter from a cask where the dose rate 2 meters from its transport vehicle was the regulatory limit value of 10 millirem per hour [49 CFR 173.441];
- A first responder (maximally exposed individual) would stay at a location between 2 and 10 meters from an undamaged shipping cask for one hour;
- The time to recover a cask following an accident would be 12 hours but no individual would remain close to a cask for this period of time;
- Accidents could occur in areas having urban, suburban, and rural populations;
- The number of accidents for a mode of transport in rural, suburban, and urban population zones in a state would be equal to the product of the distance shipments travel in all respective population zones in a state, the number of shipments, and the applicable accident rate reported by Saricks and Tompkins (DIRS 103455-1999, Tables 4 and 6);
- The density of population surrounding an accident is the density of population in a region of influence from 30 meters to 800 meters from a route escalated to account for population growth to 2035 (see Sections 2.0 and 3.0);
- The collective radiological dose to an affected population that could result from accidents considered in this section is estimated to 800 meters from the accident location. The

collective radiation dose is external and is approximately inversely proportional to the square of the distance of the affected population from the accident. Any additional estimated dose to a population more than 800 meters from the accident would be negligible and insignificant. Therefore, this accident analysis, unlike analyses of accidents that could involve release of radioactive material, does not include populations out to 80 kilometers.

- The truck cask length is shown in Table 4-8. The rail cask lengths are shown in Table 4-12.

- No additional accident related impacts would occur to populations or maximally exposed individuals following accident recovery.

5.3.2.6.3.2 Accidents in which shielding could be lost

DOE used the following assumptions and data to analyze the impacts of accidents where shielding could be lost.

- The method and assumptions for calculating dose rate from a cask in accidents where shielding would be lost is the method used in Sprung et al. (DIRS 152476-2000, p.8-49). Parameter values are shown in Table 5-51 include the parameters in Table 8.12 of Sprung et al. (DIRS 152476-2000).

- The dose rate at 1 meter from a damaged shipping cask in 0.01 percent of rail transportation accidents would be equal to the dose rates estimated in Table 5-52 for each of six categories of severe accidents; Table 5-52 was derived from Table 5-51 by the method shown in Section 5.3.2.2.2.

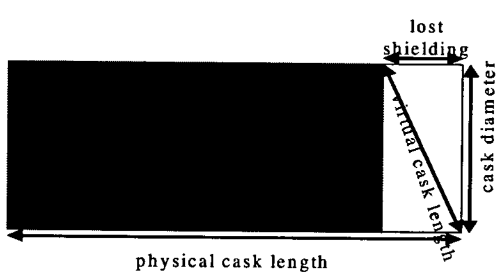

Figure 5-7. Diagram of side view of cask that has suffered loss of shielding.

- The "conditional probability of [a particular] severity" is calculated by multiplying the sum of the conditional probabilities of the basic rail cases by the probability of an end or corner impact (DIRS 152476-Sprung et al. 2000, pp. 7-28 to 7-29). No loss of shielding is assumed to occur with the third possible impact orientation, a side impact. The fraction of shielding that would be lost is depicted in Figure 5-7.

- The "source strength" of a single PWR assembly in a steel-lead-steel rail cask that has lost all lead shielding is calculated in Sprung et al. (DIRS 152476-2000, p. 8-51) to be 20 rem per hour.

- For loss-of-shielding calculations, it was also assumed that residents within 0.8 kilometer (0.5 mile) of the accident would be exposed for 12 hours

- A first responder (maximally exposed individual) could stay at the location 2 to 10 meters from a damaged cask, at a position along the length of the cask where the dose rate would be highest; for 30 minutes.

- The time to recover a cask following an accident would be 12 hours but no individual would remain close to a cask for this period of time;

- For use in the RADTRAN 5 analysis, the length of the cask is assumed to be the diagonal length of the area of the cask that would emit the highest level of radiation following loss of shielding. This length is presented in Table 5-52 for each of 6 categories of severe accident;

- The density of population surrounding an accident is the density of population in a region of influence from 30 meters to 800 meters from a route escalated to account for population growth to 2035 (see Sections 2 and 3);

- The collective radiological dose to an affected population that could result from accidents considered in this section is estimated to 800 meters from the accident location. The collective radiation dose is external and is approximately inversely proportional to the square of the distance of the affected population from the accident. Any additional estimated dose to a population more than 800 meters from the accident would be negligible and insignificant. Therefore, this accident analysis, unlike analyses of accidents that could involve release of radioactive material, does not include populations out to 80 kilometers.

- For use in the RADTRAN 5 analysis, the length of the cask is assumed to be the diagonal length of the area of the cask that would emit the highest level of radiation following loss of shielding. This length is presented in Table 5-52 for each of 6 categories of severe accident.

- No additional accident related impacts would occur to populations or maximally exposed individuals following accident recovery.

The analysis used in the RADTRAN 5 computer program to calculate unit risk factors for population dose and estimates of dose to maximally exposed individuals, used the following parameters:

- The assumed diameter of the radiation source area of a cask (1.65 meters),
- The diagonal length of the unshielded area (the "virtual cask length"), and
- The estimated effective strength of the source of radiation from the unshielded area of the cask (see Table 5-51).

The calculation of the collective population dose from a loss-of-shielding accident is based on the source terms presented in Sprung et al. (DIRS 152746-2000, p. 8-50). Table 5-51 shows the results.

1. Column 1 of Table 5-51 lists the loss-of-shielding cases evaluated by Sprung et al. (DIRS 152476-2000, Section 8.12).

2. Column 2 shows the accident condition (end impact, corner impact, fire, fire combined with shell puncture) that could result in loss-of-shielding (LOS).

3. Column 3 presents the cases from Sprung et al. (DIRS 152476-2000, p. 7-76 that are combined into each of the 11 LOS cases of Sprung et al.

4. Column 4 presents the conditional probability of occurrence for each LOS severity category in Column 1. This conditional probability was determined by summing the probabilities of the cases grouped in Column 4 and assigned to the category in Column 1.

5. Column 5 presents the conditional probability of each of the accident conditions shown in Column 2 (Sprung et al. DIRS 152476-2000, p. 7-60).

6. Column 6, presenting the products of Columns 4 and 5, shows the conditional probability of each of the 11 LOS cases.

7. Column 7, the fraction of lead shielding lost, is presented in Table 8.12 of Sprung et al. (DIRS 152476-2000).

8. Column 8, the source strength multiplier, was determined as described on p. 8-49 of Sprung et al. (DIRS 152476-2000).

9. Column 9, the source strength, is the product of Column 8 and 20 rem per hour (the estimated gamma dose from a fuel assembly shielded only by the inner and outer steel walls of the cask and by self-shielding).

Table 5-51 Loss-of-shielding analysis data from Sprung et al. (152476-2000, Section 8.12)

1. Loss of shielding case	3. LOS Accident condition	4. Rail accident case(s) in which LOS accident condition occurs	5. Sum of rail accident case probabilities	6. Probability of LOS condition occurring in accident	7. Probability of accident with LOS condition	8. Fraction of shield lost	9. Source strength multiplier	10. Source (rem per hour at 1 meter from cask)
(152476-Sprung 2000 et al., Section 8.12)		(152476-Sprung 2000 et al., Section 8.12)	(152476-Sprung 2000 et al., p. 7-76)			(152476-Sprung 2000 et al., Section 8.12)	(152476-Sprung 2000 et al., Section 8.12)	
			A	B	A x B		C	C x 20 rem per hour
1	End impact	4, 5, 6	3.05E-05	0.056	1.71E-06	0.052	0.215	4.30
2	End impact	1, 7, 8, 9	8.27E-06	0.056	4.63E-07	0.158	0.637	12.7
3	End impact	2, 10, 11, 12	5.73E-07	0.056	3.21E-08	0.264	1.017	20.0
4	End impact	3, 13, 14, 15	4.52E-09	0.056	2.53E-10	0.368	1.336	26.7
5	Corner impact	4, 5, 6	3.05E-05	0.72	2.20E-05	0.033	0.137	2.74
6	Corner impact	1, 7, 8, 9	8.27E-06	0.72	5.97E-06	0.096	0.394	7.88
7	Corner impact	2, 10, 11, 12	5.73E-07	0.72	4.14E-07	0.158	0.637	12.7
8	Corner impact	3, 13, 14, 15	4.52E-09	0.72	3.27E-09	0.255	0.986	19.7
9	Lead melt (T>350 C)	20	4.91E-05	1.0	4.90E-05	0.029	0.120	2.40
10	Lead melt & impact with puncture of external shield wall (T>350 C)	16, 17, 18, 19	4.15E-10	4.0	1.66E-09	0.5	1.668	33.4
11	No shielding loss	21				0.0	1.0	0.014

The 11 cases from Sprung et al. (DIRS 152476-2000, Table 8.12) are grouped in 6 severity categories using the following logic:

1. LOS cases (column 1 of Table 5-51) that are correlated to the same collection of rail accident cases (column 4) were grouped into the one database accident severity category. Thus LOS cases 1 and 5 were collected into a single severity category: Severity Category 5. [

2. LOS cases 2 and 6 were collected into Severity Category 2.

3. LOS cases 3 and 7 were collected into Severity Category 4.

4. LOS cases 4 and 10 were collected into Severity Category 6. Loss of shielding case 9 (DIRS 152476-Sprung et al., 2000, Table 8.12), which represents the same conditions as case 20 of Sprung et al. (p. 7-76), was assigned to Severity Category 3.

5. The case in which accidents would not be severe enough to result in loss of shielding (DIRS 152476-Sprung et al.: LOS case 11 in Table 8.12 and rail case 21 on p. 7-76) was assigned to Severity Category 1.

The conditional probabilities in Table 5-52 are the sums of the conditional probabilities of the respective LOS cases from Sprung et al. (DIRS 152476-2000, Table 8.12); e.g., the conditional probability of Severity Category 2 is the sum of the conditional probabilities of Sprung et al., cases 2 and 6.

The fraction of shielding lost (LOS fraction) for each severity category in Table 5-52 is estimated from a combination of LOS fractions for the grouped severity categories using Equation 5-17:

$$F_{SC} = \frac{\sum P_j * F_{LOS,j}}{\sum_j P_j}$$

where:

	F_{SC}	=	the LOS fraction of the "new" accident severity category SC
	j	=	the cases included in severity category SC
	P_{Cj}	=	the case *j* probability
	$F_{LOS,j}$	=	the LOS fraction of Case j

For example, the LOS fraction of Severity Category 2, which is a combination of Sprung et al. (DRIS 152476-2000, cases 2 and 6), may be calculated as follows (with reference to Table 5-51):

$$F_{SC2} = \frac{4.63 * 10^{-7} * 0.158 + 5.97 * 10^{-6} * 0.096}{(0.453 + 5.97) * 10^{-6}} = 0.10$$

The source strength multipliers are calculated in a similar manner.

Table 5-52 RADTRAN 5 input parameters used to calculate unit risk factors and MEI doses for loss-of-shielding accidents

EIS accident analysis severity category	152476 (Sprung, et al., Table 8.12) LOS case	Conditional probability of LOS severity category	Fraction of shield lost	Cask axis length of unshielded area[b]	Diagonal length of loss-of-shield area[c]	Source strength multiplier	Source (rem per hour at 1 meter)
1[a]	11	0.9999	0.0	5.1	5.1	1.0	0.014
2	2, 6	6.4E-06	0.10	0.51	1.7	0.41	8.2
3	9	4.9E-05	0.029	0.15	1.7	0.12	2.4
4	3, 7	4.5E-07	0.17	0.84	1.9	0.66	13.3
5	1, 5	2.4E-05	0.034	0.17	1.7	0.14	2.9
6	4, 8, 10	5.2E-09	0.34	1.7	2.4	1.2	24.4

a. Accidents (99.99 percent) that would not result in loss of shielding are grouped into Case 1
b. All casks are assumed to be 5.08 meters long
c. The diameter of the radioactive source for all casks is assumed to be 1.65 meters, which is approximately the diameter of the pay-load cavity of a large rail cask.

Table 5-53. RADTRAN files in Attachment 532B. (1 of 3)

Filename[a]	Size (bytes)	Date	Isotope
bigp2.in5	8,000	7/13/01	AC-228
bigp2.in5	8,000	7/13/01	AC-225
bigp2.in5	8,000	7/13/01	AM-241
bigp2.in5	8,000	7/13/01	AM-242
bigp2	139,000	7/13/01	AM-242
bigp2.in5	9,000	7/13/01	AM-242m
bigp2.iso	8,000	7/13/01	AM-242m
bigp2.in5	8,000	7/13/01	AM-243
bigp2	139,000	7/13/01	AM-243
bigp1	140,000	7/18/01	BA-137
bigp1.in5	9,000	7/18/01	C-14
bigp1.in5	9,000	7/18/01	CD-113
bigp1.iso	9,000	7/18/01	CD-113
bigp1.in5	9,000	7/18/01	CF-252
bigp1.in5	9,000	7/18/01	CL-36
bigp1	140,000	7/18/01	CL-36
bigp2.in5	8,000	7/13/01	CM-242
bigp2.in5	8,000	7/13/01	CM-243
bigp2.in5	8,000	7/13/01	CM-243
bigp2.iso	8,000	7/13/01	CM-243
bigp2.in5	9,000	7/13/01	CM-244
bigp2.in5	8,000	7/13/01	CM-246
bigp2.in5	8,000	7/13/01	CM-247
bigp1.in5	9,000	7/18/01	CO-58
bigp1.in5	9,000	7/18/01	CO-60
bigp1.iso	9,000	7/18/01	CO-60
bigp1.in5	9,000	7/18/01	CR-51
bigp1	140,000	7/18/01	Crud deposition
bigp1.in5	9,000	7/18/01	CS-135
bigp1.in5	9,000	7/18/01	CS-137

Table 5-53. RADTRAN files in Attachment 532B. (2 of 3)

Filename[a]	Size (bytes)	Date	Isotope
bigp1.in5	9,000	7/18/01	CS-137 + deposition
bigp1.iso	9,000	7/18/01	CS-137 + deposition
bigp1.in5	9,000	7/18/01	EU-154
bigp1.iso	9,000	7/18/01	EU-154
bigp1.in5	9,000	7/18/01	EU-155
bigp1.iso	9,000	7/18/01	EU-55
bigp1.in5	9,000	7/18/01	FE-55
bigp1.iso	9,000	7/18/01	FE-55
bigp1.in5	9,000	7/18/01	FE-59
bigp1.iso	9,000	7/18/01	FE-59
bigp1	140,000	7/18/01	H-3
bigp1	140,000	7/18/01	I-129
bigp1.iso	9,000	7/18/01	KR-85
bigp1.in5	9,000	7/18/01	MN-54
bigp1.iso	9,000	7/18/01	MN-54
bigp1.iso	9,000	7/18/01	NB-93m
bigp1.iso	9,000	7/18/01	NB-94
bigp1.iso	9,000	7/18/01	NB-95
bigp1.iso	9,000	7/18/01	NI-59
bigp1.in5	9,000	7/18/01	NI-59
bigp1.in5	9,000	7/18/01	NI-63
bigp1.iso	9,000	7/18/01	NI-63
bigp2.in5	8,000	7/13/01	NP-237
bigp2	139,000	7/13/01	PA-231
bigp2	139,000	7/13/01	Particulate deposition
bigp2.in5	8,000	7/13/01	PB-210
bigp1.in5	9,000	7/18/01	PM-147
bigp1.iso	9,000	7/18/01	PR-143
bigp1	140,000	7/18/01	PR-144
bigp2.in5	8,000	7/13/01	PU-236
bigp2.in5	8,000	7/13/01	PU-238
bigp2.in5	8,000	7/13/01	PU-239
bigp2.in5	8,000	7/13/01	PU-240
bigp2.in5	8,000	7/13/01	PU-240
bigp2.in5	8,000	7/13/01	PU-241
bigp2.in5	8,000	7/13/01	PU-242
bigp2.in5	8,000	7/13/01	PU-244
bigp2.in5	8,000	7/13/01	RA-226
bigp2	139,000	7/13/01	RA-228
bigp1.in5	9,000	7/18/01	RH-102
bigp1.iso	9,000	7/18/01	RH-102
bigp1	140,000	7/18/01	RH-106
bigp1.in5	9,000	7/18/01	RU-106
bigp1.iso	9,000	7/18/01	S-35
bigp1.iso	9,000	7/18/01	SB-125
bigp1.in5	9,000	7/18/01	SB-126m
bigp1.in5	9,000	7/18/01	SCB-125
bigp1	140,000	7/18/01	SE-79
bigp1.in5	9,000	7/18/01	SM-151
bigp1.in5	9,000	7/18/01	SN-119m
bigp1.in5	9,000	7/18/01	SN-126
bigp1.iso	9,000	7/18/01	SN-126
bigp1.in5	9,000	7/18/01	SR-90

Table 5-53. RADTRAN files in Attachment 532B. (3 of 3)

Filename[a]	Size (bytes)	Date	Isotope
bigp1.iso	9,000	7/18/01	SR-90
bigp1.in5	9,000	7/18/01	TC-99
bigp1.in5	9,000	7/18/01	TE-125m
bigp1.in5	9,000	7/18/01	TE-129
bigp1.in5	9,000	7/18/01	TE-129m
bigp1	139,000	7/18/01	TH-229
bigp1	139,000	7/18/01	U-232
bigp2.in5	8,000	7/13/01	U-233
bigp2.iso	8,000	7/13/01	U-234
bigp2	139,000	7/13/01	U-235
bigp2.iso	8,000	7/13/01	U-236
bigp2.in5	8,000	7/13/01	U-238
bigp1.in5	9,000	7/18/01	Y-90
bigp1.iso	9,000	7/18/01	Y-90
bigp1	140,000	7/18/01	ZR-93
bigp1.in5	9,000	7/18/01	ZR-95
Loss-of-Shielding files			
LOSMEITR00.OUT	18,575	5/17/01	Loss-of shielding-truck-MEI
losrail_00.in5	2,621	5/18/01	Loss-of shielding-rail
losrail_00.out	16,606	5/18/01	Loss-of shielding-rail
losrailmei.in5	3,492	5/18/01	Loss-of shielding-rail-MEI
losrailmei_0.out	20,929	5/18/01	Loss-of shielding-rail-MEI

Table 5-54. RADTRAN files in Attachment 532B.

Filename[a]	Size (bytes)	Date	Isotope
losrailmei0.out	18,127	5/18/01	Loss-of shielding-rail-MEI
lostruck_0.in5	2,636	5/18/01	Loss-of shielding-truck
lostruck_00.out	16,184	5/18/01	Loss-of shielding-truck
lostruckmei0.out	21,105	5/18/01	Loss-of shielding-truck-MEI
lostruckme.in5	3,692	5/18/01	Loss-of shielding-truck-MEI
Other files			
Grounddep_Rev1.xls			Excel file showing calculation of ingestion unit risk factor.

a. The extension *.in5 indicates a RADTRAN 5 input file; the extension *.out indicates a RADTRAN output file; the extension *.xls indicates a RADTRAN output file that has been saved as an Excel file.

5.3.3 CONSEQUENCES OF MAXIMUM REASONABLY FORESEEABLE ACCIDENTS

5.3.3.1 Introduction

This section presents the methodology and results for the transportation accident scenarios that would have annual probabilities exceeding 1 in 10 million (10^{-7}) and would have the highest consequences. This threshold is the probability threshold below which accidents are not considered to be reasonably foreseeable (DIRS 104601-DOE 1993, p. 28). Also presented in this section are estimated probabilities for severe accidents for each of the material types that would be shipped under the Proposed Action for both the mostly legal-weight truck scenario and the mostly rail scenario.

The section also presents the approach and data used in the analysis to estimate the size and area distribution for urbanized area populations. The population data were used in estimating consequences of maximum reasonably foreseeable accidents that were postulated to occur in urbanized areas. The methodology used to estimate the consequences of the maximum reasonably foreseeable accident is presented. This section includes the atmospheric conditions modeled and the results of the analysis. Finally, this section presents the estimated consequences for a maximum reasonably foreseeable accident for each material type that would be shipped.

5.3.3.2 Method

This section discusses the data and methodology used to estimate consequence of maximum reasonably foreseeable accidents. The conditional probability estimates, population estimates, radionuclide inventory, meteorology, analysis of MEIs, and a discussion of accident scenarios analyzed are presented.

Annual frequency of maximum reasonably foreseeable accidents. The selection of the accident scenario for the maximum reasonably foreseeable transportation accident was based on four factors. Annual accident frequencies were determined based on the conditional probability (that is, the probability that an accident will have a particular severity if it occurs) from Sprung et al. (DIRS 152476-2000, Chapter 7), state-specific accident rates for each route Saricks and Tompkins (DIRS 103455-1999, Tables 4 and 6), the fraction of travel in an urbanized or rural area, and the probability of certain meteorology conditions (stability class D or F).

Population densities used in consequence analysis. The estimation of consequences for the maximum reasonably foreseeable accidents used the population density estimates from 0 to 80 kilometers (50 miles) for the most populous urbanized areas (plus Las Vegas) in the country. The Environmental Baseline file for National Transportation (DIRS 104800-CRWMS M&O 1999, all) identifies the 20 most populous urbanized areas in the United States (Table 5-55). The 20 largest urbanized areas were identified in the U.S. Bureau of the Census (DIRS 103158-Bureau of the Census 1992, Table 8). Although Las Vegas was not one of the 20 most populous urbanized areas, it was included for estimating population densities for urbanized areas. Also, the average daily population of visitors to Las Vegas was added to the Las Vegas population data. The analysis assumed the visitor population in the Las Vegas metropolitan area would be concentrated in the 8.05-kilometer (5-mile) diameter core of the city.

The central coordinates (longitude and latitude) for these urbanized areas were obtained from the U.S. Bureau of the Census, Census Geographic Information Coding Scheme (DIRS 104800-CRWMS M&O 1999, Table 6-1). The populations at 0 to 8 kilometers (0 to 5 miles), 0 to 16 kilometers (0 to 10 miles), 0 to 24 kilometers (0 to 15 miles), 0 to 32 kilometers (0 to 20 miles), 0 to 40 kilometers (0 to 25 miles), and 0 to 80 kilometers (0 to 50 miles) from these central points were obtained from the U.S. Environmental

Table 5-55. Populations of the top 20 urbanized areas in the United States (plus Las Vegas, Nevada).

Urbanized Area	Population (0 – 80 km, 1990 Census data)[a]
New York	16,745,143
Los Angeles	11,995,083
Chicago	7,997,522
Philadelphia	7,417,369
Detroit	4,645,291
San Francisco	5,343,862
Washington	5,590,633
Dallas	3,923,686
Houston	3,680,606
Boston	5,998,075
San Diego	2,530,629
Atlanta	3,099,872
Minneapolis	2,648,573
Phoenix	2,184,434
St. Louis	2,566,376
Miami	3,446,036
Baltimore	5,520,605
Seattle	2,983,686
Tampa	2,792,637
Pittsburgh	2,969,521
Las Vegas	1,464,995[b,c]

a. To convert kilometers to miles, multiply by 0.62.
b. Includes average daily visitor population of 292,000.
c. Obtained using coordinates of (36.17432, 115.15408) as input

Protection Agency Geographic Information Query System (DIRS 104800-CRWMS M&O 1999, Table 6-2). These populations are based on 1990 Census data. Based on these data and areas, population densities were determined for 0 to 8 kilometers (0 to 5 miles), 8 to 16 kilometers (5 to 10 miles), 16 to 24 kilometers (10 to 15 miles), 24 to 32 kilometers (15 to 20 miles), 32 to 40 kilometers (20 to 25 miles), and 40 to 80 kilometers (25 to 50 miles) (DIRS 104800-CRWMS M&O 1999, Table 6-2). Similarly, the population densities from 0 to 80 kilometers for the Las Vegas area were determined.

The population densities for each of the top 20 most populous urbanized areas and Las Vegas, for each concentric ring from 0 to 80 kilometers were then combined to determine the average population density (based on 1990 Census data) for each concentric ring. These densities were then increased based upon escalation factors presented in Section 3.4 for each of the urbanized areas listed in Table 5-55. The population densities from 0 to 80 kilometers (0 to 50 miles) for Las Vegas and the top 20 urbanized areas are presented in Table 5-56. The urbanized area population density and distance data were used by the analysis to evaluate the consequences of maximum reasonably foreseeable accidents and sabotage events. Consequences are estimated for each of the concentric rings from 0 to 50 miles (0 to 5 miles, 5 to 10 miles, 10 to 15 miles, 15 to 20 miles, 20 to 25 miles, and 25 to 50 miles) separately using the RISKIND code and summed to determine the total accident consequence.

Table 5-56 summarizes the population density data average over the top 20 urbanized areas (plus Las Vegas) in the country.

Table 5-56. Average top 20 urbanized area population information 0 to 80 kilometers (plus Las Vegas, Nevada) – 1990 Census data

Ring Letter	Radius (km)	Area of Circle (km^2)	Population Inside Circle	Population Density (persons/ km^2)	Donut Distance	Population Inside Donut	Area of Donut (km^2)	Donut Population Density (persons/km^2)
A	8.05	203.33	553,025	2,720	0 to 8.05	553,025	203.33	2,720
B	16.09	813.32	1,509,941	1,857	8.05 to 16.09	956,917	609.99	1,569
C	24.14	1829.97	2,282,968	1,248	16.09 to 24.14	773,027	1,016.65	760
D	32.18	3253.28	2,891,397	889	24.14 to 32.18	608,429	1,423.31	427
E	40.23	5083.26	3,359,718	661	32.18 to 40.23	468,321	1,829.98	256
F	80.45	20333.02	5,025,935	247	40.23 to 80.45	1,666,217	15,249.76	109

Radioactive contents of casks for analyzing consequences of maximum reasonably foreseeable accidents. The analysis based the calculation of consequences of maximum reasonably foreseeable accidents on representative PWR SNF described in Section 5.3 of this document. The PWR fuel constitutes the largest part of the inventory that would be shipped to the repository under the Proposed Action. Calculations were also performed for other types of materials, including BWR SNF, DOE spent fuel, and HLW. The greatest consequences were obtained in accidents for representative PWR SNF shipped in steel-lead-steel rail casks.

DOE provided radionuclide inventories for each material type analyzed (see Attachment 2A). The analysis used estimates of releases (cask inventory times release fractions) to the atmosphere as a source term and the RISKIND computer code (DIRS 101483-Yuan et al. 1995, all) to calculate radiological consequences to hypothetical MEIs and populations. The consequences were estimated for rural and urbanized area (urban and suburban areas) populations postulated to live within 80 kilometers (50 miles) of the location of a severe accident.

Postulated atmospheric conditions during severe accidents. The analyses of accident consequences assumed that releases of radioactive materials from casks during and following severe accidents would be into the atmosphere where the materials would be carried by wind (The same would be true for releases caused by an act of sabotage; see below). Because it is not possible to predict specific locations where transportation accidents would occur, the analysis used data that describe average atmospheric conditions for the continental United States. These data can be found in the Environmental Baseline File for national transportation (DIRS 104800-CRWMS M&O 1999, Section 10). To estimate national average atmospheric conditions for use in the RISKIND computer code (DIRS 101483-Yuan et al. 1995, all), these data (joint frequency data from 177 sites) were averaged and normalized. In performing the averaging and normalization, the directional component of the joint frequency data was condensed to yield a two-dimensional matrix of stability class and windspeed class, which is the format used by RISKIND.

The joint frequency data were obtained from Yuan et al. (DIRS 101483-1995, all). To provide a consistent format for RISKIND, only data sets with stability classes A through F or A through G were used. In those cases where a data set contained both stability class F and G, these data were consolidated, again to provide data in a consistent format for RISKIND.

This averaging of data resulted in the designation of average, expected weather conditions as D stability class and a wind speed of 4.77 meters per second (10.67 miles per hour). Stable conditions, which would lead to greater consequences by which would occur much less often, were equated with F stability class and a wind speed of 0.89 meters per second (2 miles per hour).

RISKIND uses a Gaussian dispersion model to calculate the dispersions of plumes of gases and particles. RISKIND has been used for similar calculations in other EISs and has been verified as an appropriate tool for this purpose (DIRS 101845-Maheras and Pippen 1995, all). Using calculated dispersions for each possible meteorological condition, RISKIND calculated values for radiological consequences (population dose and dose to an MEI). Because atmospheric conditions that are called neutral, or average, conditions would be the conditions expected to prevail during a severe accident or act of terrorism and they are assigned a likelihood of one. Stable, quiescent conditions, which are expected to prevail about 10 percent of the time, and are assigned a likelihood of 0.1. Consequences are estimated for both neutral and stable conditions for each of the accident scenarios analyzed.

Release height. The RISKIND code estimates the release height of the plume based upon the initial release height of the plume (cask height) and any heat input due to a fire. Typically, F stability will give lower effective plume heights than D stability. For the analysis of maximum reasonably foreseeable accidents, a release height of 10 meters (33 feet) was assumed for all conditions without accounting for the buoyancy of the plume due to fire conditions. In the case of an accident scenario with a fire, a 10-meter release height with no heat input results in an underestimate of plume rise and consequently a conservative estimate of consequences.

Analysis of impacts to MEIs for maximum reasonably foreseeable accidents. The Yucca Mountain EIS also analyzed consequences for MEIs during maximum reasonably foreseeable accidents. The consequences for these individuals were determined by specifying hypothetical locations for MEIs to ascertain the location of the highest dose (to MEIs).

Maximum reasonably foreseeable accident scenarios. The accident scenarios presented in DIRS 152476 (Sprung et al. 2000, Chapter 7) and analyzed for the maximum reasonably foreseeable accidents include impact, fire, and impact with fire events. PWR SNF in a steel-lead-steel rail cask and in a steel-depleted uranium-steel truck cask was analyzed for consequences of the maximum foreseeable accident. The conditional probabilities (probability of specified accident conditions if an accident occurs) and the release fractions of the accident scenarios analyzed in identifying the maximum reasonably foreseeable accident for steel-lead-steel rail casks are presented in Figure 5-4. Similarly, Figure 5-2 in Section 5.3.2 shows the conditional probabilities and release fractions for a steel-depleted uranium-steel truck cask.

5.3.3.3 Assumptions

The following assumptions were used to estimate consequences maximum reasonably foreseeable accidents:

- Release height of the plume is 10 meters (33 feet) for both fire and impact event scenarios. Modeling the heat release rate of accident scenarios involving fire would result in lower consequences than modeling all events with a 10-meter release height.

- Breathing rate for individuals is assumed to be 10,400 cubic meters per year (376,000 cubic feet) (DIRS 150898-Neuhauser and Kanipe 2000, p. 3-18.).

- Long-term exposure to contamination deposited on the ground is assumed to be 1 year with no interdiction or cleanup.

- Short-term exposure to airborne contaminants is assumed to be 2 hours.
- To account for the photon energy of certain short-lived daughter products, the photon energy of the daughter was added to the parent and the half-life of the daughter was neglected.
- The release fractions from DIRS 152476 (Sprung et al. 2000, Chapter 7) assumed that all of the material released was aerosolized and respirable. Therefore, there was no contribution to consequences from nonrespirable particles.

5.3.3.4 Use of Computer Software and Models

The RISKIND computer program (DIRS 101483-Yuan et al. 1995, all) was used to estimate scenario-specific doses to MEIs for both routine operations and accident conditions and to estimate population impacts for the assessment of accident scenario consequences. In addition, the RISKIND code has been verified and benchmarked (DIRS 102060-Biwer et al. 1997, all).

The RISKIND code was run on a personal computer running Windows 2000.

5.3.3.5 Calculation/Analysis and Results

Consequences of maximum reasonably foreseeable accidents. The RISKIND calculations provided estimates of population dose (person-rem) and dose to hypothetical MEIs (rem). The analysis converted these doses to estimated numbers of LCFs using the risk factor of 5.0E-04 fatal cancers per person-rem for members of the general public recommended by the International Commission on Radiological Protection (DIRS 101836-ICRP 1991, p. 70).

The estimated annual frequency and consequence for accidents for each of the cells in the matrix in Figure 5-4 for a steel-lead-steel rail cask are presented in Table 5-57 for both urbanized and rural areas for stability class F weather conditions. The consequences associated with stability class D weather conditions were also calculated but are lower than those for stability class F.

Table 5-58 presents the consequences and frequencies for truck casks accidents. The case number listed in Table 5-57 and 5-58 corresponds to the severity cases presented in Sprung et al. 2000 (DIRS 152476-Chapter 7).

Table 5-59 presents the results of analyses for the 8-kilometer (5-mile) radius area surrounding an accident location of maximum consequences for nine different shipment inventories, including PWR SNF and BWR SNF. The results show that accidents involving shipments of PWR fuel would have the highest consequences. The key in Table 5-60 defines the fuel types presented in Table 5-59. A description of the DOE SNF types is provided in Table 5-61.

Table 5-62 lists the files that can be found in Attachment 53B.

An additional MEI would be the first responder to an accident in which there is only loss of shielding (no release of radioactive material) or an accident in which the vehicle is stopped but undamaged. Analysis of such accidents is discussed in Section 5.3.2.6. The dose risk to the first responder is shown in Table 5-63.

Table 5-57. Frequency and consequence of rail accidents[a].

Rail Cask					
Case #	**Expected Frequency (per year)**	**Total exposure (person-rem)**	**Case #**	**Expected Frequency**	**Total exposure (person-rem)**
Urban Area - Stability Class F			**Rural Area - Stability Class F**		
Rail 19	7.67E-19	254,377	Rail 19	4.71E-18	419
Rail 15	7.67E-16	254,377	Rail 15	4.71E-15	419
Rail 14	5.77E-15	242,817	Rail 14	3.54E-14	400
Rail 13	2.07E-13	230,214	Rail 13	1.27E-12	379
Rail 16	2.32E-12	220,788	Rail 16	1.43E-11	364
Rail 3	2.51E-11	219,698	Rail 3	1.54E-10	361
Rail 18	9.74E-17	173,447	Rail 18	5.99E-16	285
Rail 12	9.74E-14	173,447	Rail 12	5.99E-13	285
Rail 11	7.34E-13	171,358	Rail 11	4.51E-12	282
Rail 6	6.16E-10	159,807	Rail 6	3.78E-09	264
Rail 10	2.62E-11	149,279	Rail 10	1.61E-10	246
Rail 2	3.18E-09	149,266	Rail 2	1.95E-08	245
Rail 17	1.41E-15	112,468	Rail 17	8.63E-15	185
Rail 9	1.41E-12	81,049	Rail 9	8.63E-12	134
Rail 20	2.75E-07	9,893	Rail 20	1.69E-06	16.3
Rail 8	1.05E-11	3,416	Rail 8	6.47E-11	5.63
Rail 7	3.79E-10	3,060	Rail 7	2.33E-09	5.04
Rail 1	4.59E-08	2,933	Rail 1	2.82E-07	4.83
Rail 5	4.61E-09	1,745	Rail 5	2.83E-08	2.88
Rail 4	1.66E-07	1,346	Rail 4	1.02E-06	2.22

a. Source of rail accidents: DIRS 152476 (152476-Sprung et al. 2000, p. 7-76).

Table 5-58. Frequency and consequence of truck accidents[a].

Truck Cask					
Case #	Expected Frequency (per year)	Total exposure (person-rem)	Case #	Expected Frequency	Total exposure (person-rem)
Urban Area - Stability Class F			Rural Area - Stability Class F		
LWT 14	2.8E-12	36,798	LWT 14	1.6E-11	60.7
LWT 15	1.3E-16	18,919	LWT 15	7.6E-16	31.1
LWT 4	2.8E-09	8,484	LWT 4	1.6E-08	14
LWT 7	1.3E-13	5,203	LWT 7	7.6E-13	8.57
LWT 12	9.8E-16	1,251	LWT 12	5.5E-15	2.07
LWT 9	7.7E-14	1,251	LWT 9	4.4E-13	2.07
LWT 11	6.0E-12	1,146	LWT 11	3.4E-11	1.88
LWT 8	4.7E-10	1,146	LWT 8	2.7E-09	1.88
LWT 1	6.2E-10	1,125	LWT 1	3.5E-09	1.85
LWT 18	2.3E-07	1,083	LWT 18	1.3E-06	1.79
LWT 6	3.7E-12	723	LWT 6	2.1E-11	1.19
LWT 5	2.0E-08	581	LWT 5	1.1E-07	0.92
LWT 3	1.1E-08	291	LWT 3	6.4E-08	0.48
LWT 2	2.5E-06	225	LWT 2	1.4E-05	0.37

a. Source of truck accidents: Sprung et al. (DIRS 152476-2000, p. 7-73).

Table 5-59. Maximum consequence comparisons.

Stability Class D - Rail Cask								
Fuel Type	RD10-17	RD1-17	RD1-1-24	RD11-17	RD12-17	RD12-24	RD13-17	RD16-17
Consequence (0 - 8 km)	757	1310	584	2520	1910	851	3030	784
Consequence (MEI)	2.26	3.92	1.75	7.52	5.72	2.54	9.03	2.27
Stability Class F - Rail Cask								
Consequence (0 - 8 km)	3100	5380	2390	10300	7840	3490	12400	3210
Consequence (MEI)	9	15.6	6.95	30	22.8	10.1	36	9.02
Stability Class D - Truck Cask								
Fuel Type	TD4-17	TD10-17	TD1-17	TD11-17	TD12-17a	TD16-17	TD13-17	TD7-17
Consequence (0 - 8 km)	179	118	20.6	28.5	122	18.5	43.1	2.14
Consequence (MEI)	0.534	0.352	0.0615	0.0853	0.0132	0.0554	0.129	0.00639
Stability Class F - Truck Cask								
Consequence (0 - 8 km)	732	482	84.3	117	499	75.9	177	8.76
Consequence (MEI)	2.13	1.4	0.245	0.339	0.0527	0.22	0.513	0.0254
Stability Class D - Rail Cask								
Fuel Type	RD2-17	RD3-17	RD4-17	RD4-24	RD5-17	RD8-17	RD9-17	RDHLW-HH
Consequence (0 - 8 km)	26.1	1.58	7650	3400	371	3.42	399	5.82
Consequence (MEI)	0.0729	0.0047	18.9	10.1	1.11	0.0102	1.19	0.0174
Stability Class F - Rail Cask								
Consequence (0 - 8 km)	107	6.44	31300	13900	1520	14	1630	23.8
Consequence (MEI)	0.29	0.0187	75.1	40.3	4.42	0.0406	4.74	0.0691
Stability Class D - Rail Cask								
Fuel Type	RDHLW-IH	RDHLW-SH	TD2-17	TD3-17	TD5-17	TD8-17	TD9-17	TD6-17
Consequence (0 - 8 km)	25	22500	0.888	0.0368	5.62	0.269	13.5	0.93
Consequence (MEI)	0.0748	67.1	0.00264	9.48E-05	0.0168	2.85E-05	0.0403	0.00276
Stability Class F - Rail Cask								
Consequence (0 - 8 km)	103	92,000	4	0	23	1	55	4
Consequence (MEI)	0.298	267.000	0.011	0.000	0.067	0.000	0.160	0.011
Stability Class D (Truck and Rail)								
Fuel Type	RDHLW-WH	TDHLW-HH	TDHLW-SH	TDHLW-IH	TDHLW-WH	RD6-17	RD7-17	
Consequence (0 - 8 km)	105	0.0995	357	0.405	1.67	18.2	77.6	
Consequence (MEI)	0.313	0.000282	1.07	0.0012	0.00498	0.0544	0.218	
Stability Class F (Truck and Rail)								
Consequence (0 - 8 km)	429	0.385	1460	1.64	6.82	74.6	318	
Consequence (MEI)	125	0.0011	4.25	0.00474	0.0198	0.217	0.868	
Stability Class D (Truck and Rail)								
Fuel Type	PWR-LWT	PWR-LWT	PWR-Rail	PWR-Rail	BWR-LWT	BWR-Rail		
Consequence (0 - 8 km)	279	211	39,100	1,920	194	33,600		
Consequence (MEI)	3.94	0.319	499	2.43	0.581	106		
Stability Class F (Truck and Rail)								
Consequence (0 - 8 km)	871	47	121,000	418	796	137,000		
Consequence (MEI)	49	0.006	5790	0.042	2	419		

Table 5-60. DOE SNF and HLW categories.

Identifier		Identifier	
RD10-17	Rail, DOE SNF Category 10, 17-inch canisters	RD2-17	Rail, DOE SNF Category 2, 17-inch canisters
RD1-17	Rail, DOE SNF Category 1, 17-inch canisters	RD3-17	Rail, DOE SNF Category 3, 17-inch canisters
RD1-1-24	Rail, DOE SNF Category 1, 24-inch canisters	RD4-17	Rail, DOE SNF Category 4, 24-inch canisters
RD11-17	Rail, DOE SNF Category 11, 17-inch canisters	RD4-24	Rail, DOE SNF Category 4, 24-inch canisters
RD12-17	Rail, DOE SNF Category 12, 17-inch canisters	RD5-17	Rail, DOE SNF Category 5, 17-inch canisters
RD12-24	Rail, DOE SNF Category 12, 24-inch canisters	RD8-17	Rail, DOE SNF Category 8, 24-inch canisters
RD13-17	Rail, DOE SNF Category 13, 17-inch canisters	RD9-17	Rail, DOE SNF Category 9, 17-inch canisters
RD16-17	Rail, DOE SNF Category 16, 17-inch canisters	RDHLW-HH	Rail, HLW- Hanford
TD4-17	Truck, DOE SNF Category 4, 17-inch canisters	RDHLW-IH	Rail, HLW - INEEL
TD10-17	Truck, DOE SNF Category 10, 17-inch canisters	RDHLW-SH	Rail, HLW - Savannah River
TD1-17	Truck, DOE SNF Category 1, 17-inch canisters	TD2-17	Truck, DOE SNF Category 2, 17-inch canisters
TD11-17	Truck, DOE SNF Category 11, 17-inch canisters	TD3-17	Truck, DOE SNF Category 3, 17-inch canisters
TD12-17a	Truck, DOE SNF Category 12, 17-inch canisters	TD5-17	Truck, DOE SNF Category 5, 17-inch canisters
TD16-17	Truck, DOE SNF Category 16, 17-inch canisters	TD8-17	Truck, DOE SNF Category 8, 17-inch canisters
TD13-17	Truck, DOE SNF Category 13, 17-inch canisters	TD9-17	Truck, DOE SNF Category 9, 17-inch canisters
TD7-17	Truck, DOE SNF Category 7, 17-inch canisters	TD6-17	Truck, DOE SNF Category 6, 17-inch canisters
RDHLW-WH	Rail, HLW - West Valley	PWR-LWT	PWR Fuel - Legal-weight truck
TDHLW-HH	Truck, HLW – Hanford	PWR-Rail	PWR Fuel - Rail
TDHLW-SH	Truck, HLW - SRS	BWR-LWT	BWR Fuel - Legal-weight truck
TDHLW-IH	Truck, HLW – INEEL	BWR-Rail	BWR Fuel - Legal-weight truck
TDHLW-WH	Truck, HLW - West Valley		
RD6-17	Rail, DOE SNF Category 6, 17 inch canisters		
RD7-17	Rail, DOE SNF Category 7, 17 inch canisters		

Acronyms: PWR = pressurized-water reactor; BWR = boiling-water reactor.

Table 5-61. DOE SNF and HLW categories.[a,b]

Number	DOE SNF category	Typically from	Description of fuel
1	Uranium metal	N-Reactor	Uranium metal fuel compounds with aluminum or zirconium alloy cladding
2	Uranium-zirconium	HWCTR	Uranium alloy fuel compounds with zirconium alloy cladding
3	Uranium-molybdenum	Fermi	Uranium-molybdenum alloy fuel compounds with zirconium alloy cladding
4	Uranium oxide, intact	Commercial PWR	Uranium oxide fuel compounds with zirconium alloy or stainless-steel cladding in fair to good condition
5	Uranium oxide, failed/declad	TMI core debris	Uranium oxide fuel compounds without cladding or with zirconium alloy, aluminum, Hastelloy, nickel-chromium, or stainless-steel cladding in poor or unknown condition
6	Uranium-aluminide	ATR	Uranium-aluminum alloy fuel compounds with aluminum cladding
7	Uranium-silicon	FRR MTR	Uranium silicide fuel compounds with aluminum cladding
8	Thorium/uranium carbide, high-integrity	Fort St. Vrain	Thorium/uranium carbide fuel compounds with graphite cladding in good condition
9	Thorium/uranium carbide, low-integrity	Peach Bottom	Thorium/uranium carbide fuel compounds with graphite cladding in unknown condition
10	Plutonium/uranium carbide, nongraphite	FFTF carbide	Uranium carbide or plutonium-uranium carbide fuel compounds with or without stainless-steel cladding
11	Mixed oxide	FFTF oxide	Plutonium/uranium oxide fuel compounds in zirconium alloy, stainless-steel, or unknown cladding
12	Uranium/thorium oxide	Shippingport LWBR	Uranium/thorium oxide fuel compounds with zirconium alloy or stainless-steel cladding
13	Uranium-zirconium hydride	TRIGA	Uranium-zirconium hydride fuel compounds with or without Incalloy, stainless-steel, or aluminum cladding
14	Sodium-bonded	EBR-II driver	Uranium and uranium-plutonium metallic alloy with predominantly stainless-steel cladding
15	Naval fuel	Surface ship/submarine	Uranium-based with zirconium alloy cladding
16	Miscellaneous	Not specified	Various fuel compounds with or without zirconium alloy, aluminum, Hastelloy, tantalum, niobium, stainless-steel or unknown cladding

Source: DIRS 104385-Fillmore 1998, all.

SNF = spent nuclear fuel; HWCTR = heavy-water cooled test reactor; PWR = pressurized-water reactor; TMI = Three Mile Island; ATR = Advanced Test Reactor; FRR MTR = foreign research reactor – material test reactor; FFTF = Fast Flux Test Facility; LWBR = light-water breeder reactor; TRIGA = Training Research Isotopes – General Atomic; EBR-II = Experimental Breeder Reactor II.

Table 5-62. Filename key-Attachment 53B.

Case	Case File Names	Description
LWT	DUTXY.inp	Depleted uranium truck cask RISKIND input file
LWT	DUTXY.out	Depleted uranium truck cask RISKIND output file
Rail	RAILXY.inp	Rail steel-lead-steel cask RISKIND input file
Rail	RAILXY.out	Rail steel-lead-steel cask RISKIND output file
File Names	Description	
X	Indicates the severity category from NUREG/CR-6672. (DIRS 152476-Sprung et al. 2000) (1-19 for a truck cask)	
Y	Indicates the concentric ring analyzed. (See Table 5-56). Also, A-N. A-F represent stability class D weather conditions and H-M represent stability class F weather conditions G and N represent MEI analysis case.	
*.INP	RISKIND input file	
*.OUT	RISKIND output file	

Table 5-63. Dose risk to an emergency first responder from a loss-of-shielding accident.

Rail MEI Dose			
Loss-of-shielding case	**Severity fraction**	**Person-rem**	**Dose risk**
1	0.9999	5.14E-03	5.14E-03
2	6.44E-06	4.83E-01	3.11E-06
3	4.90E-05	1.37E-01	6.71E-06
4	4.46E-07	8.30E-01	3.70E-07
5	2.37E-05	1.63E-01	3.86E-06
6	5.18E-09	1.98E+00	1.03E-08
		Total dose risk	**5.15E-03**
		Loss-of-shielding only	**1.41E-05**
Truck MEI Dose			
Loss-of-shielding case	**Severity fraction**	**Person-rem**	**Dose risk**
1	0.9999	2.57E-03	5.14E-03
2	4.46E-07	4.75E-01	2.12E-07
3	4.90E-05	5.91E-02	2.90E-06
4	6.44E-06	2.38E-01	1.53E-06
5	2.37E-05	7.03E-02	1.67E-06
6	5.18E-09	1.45E+00	7.52E-09
		Total dose risk	**5.15E-03**
		Loss-of-shielding only	**6.32E-06**

a. Units of dose are person-rem.

5.3.4 CONSEQUENCES OF SABOTAGE AND TERRORISM EVENTS

5.3.4.1 Introduction

The analysis considered the impacts of successful sabotage attempts on a cask. A sabotage event cannot be characterized as a random event and was, therefore, not addressed in the same way as an accident, which would be random. A study conducted by Sandia National Laboratories (DIRS 104918-Luna, Neuhauser, and Vigil 1999, all) estimated the amounts and characteristics of releases of radioactive materials from rail and truck casks subjected to the effects of two different high-energy density devices.

Devices considered in the Sandia study (DIRS 104918-Luna, Neuhauser, and Vigil 1999, all) included possible devices that might be used in acts of sabotage against shipping casks. These kinds of devices were demonstrated by the study to be capable of penetrating a cask's shield wall, leading to the dispersal of contaminants to the environment.

The truck cask design selected for analysis was the General Atomics GA-4 Legal-Weight Truck Cask. This cask, which uses uranium for shielding, is a state-of-the-art design recently certified by the Nuclear Regulatory Commission to ship four PWR nuclear fuel assemblies (DIRS 148184-NRC 1998, all). The rail cask design used was based on the conceptual design developed by DOE for the dual-purpose canister system. This design is representative of large rail casks that could be certified for shipping SNF and HLW. (Note: The shield walls of shipping casks for SNF and HLW are similar to the massive layered construction used in armored vehicles such as tanks.)

DOE used the RISKIND code (DIRS 101483-Yuan et al. 1995, all) to evaluate the radiological health and safety consequences of the estimated releases of radioactive materials. The analysis used assumptions about the concentrations of radioisotopes in SNF, population densities, and atmospheric conditions (weather) used to evaluate the maximum reasonably foreseeable accidents. Because it is not possible to forecast the location or the environmental conditions that might exist for acts of sabotage, the analysis determined impacts for urbanized areas under neutral (average) weather conditions.

The estimated impacts would be greater for an act of sabotage against a legal-weight truck shipment than against a rail shipment, even though the amount of SNF in a rail cask would be as much as six times that in a truck cask. The greater impacts would be a result of the estimate that an event involving the smaller truck cask would release greater quantities of radioactive materials (DIRS 104918-Luna, Neuhauser, and Vigil 1999, all).

5.3.4.2 Method

A successful act of sabotage on an SNF cask is treated in this analysis as a deterministic event, and no probability of success or failure was determined as was the case for transportation accidents.

Luna Neuhauser, and Vigil (DIRS 104918-1999, all) examined the effects of acts of sabotage against two kinds of SNF casks, a large rail cask and a smaller truck cask. These casks are shown in Figures 5-8 and 5-9. The rail cask was assumed to hold 26 or 24 PWR assemblies and the truck cask 4 PWR assemblies.

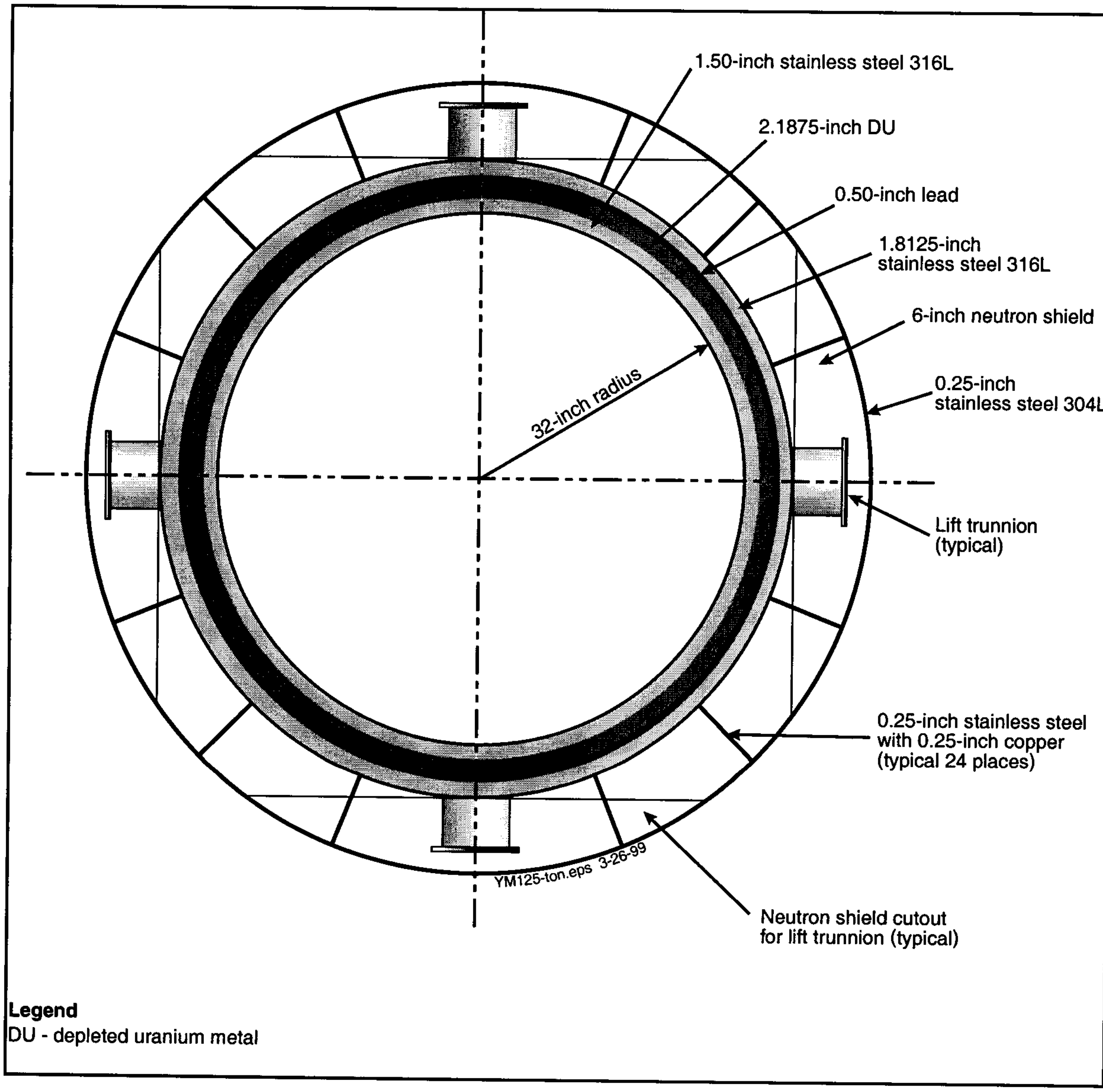

Figure 5-8. Cross sectional drawing of rail cask.

The effects of two different kinds of man-portable high-energy density devices, denoted HEDD1 and HEDD2, were examined in Luna, Neuhauser, and Vigil (DIRS 104918-1999, all). The devices were selected based on the volume of SNF they would have the potential to disrupt, which is a combination of the depth of penetration and the diameter of the penetration.

Releases from the truck and rail casks were expressed as the estimated fractional releases of the contents of the casks. These estimated release fractions are presented in Tables 5-64 and 5-65.

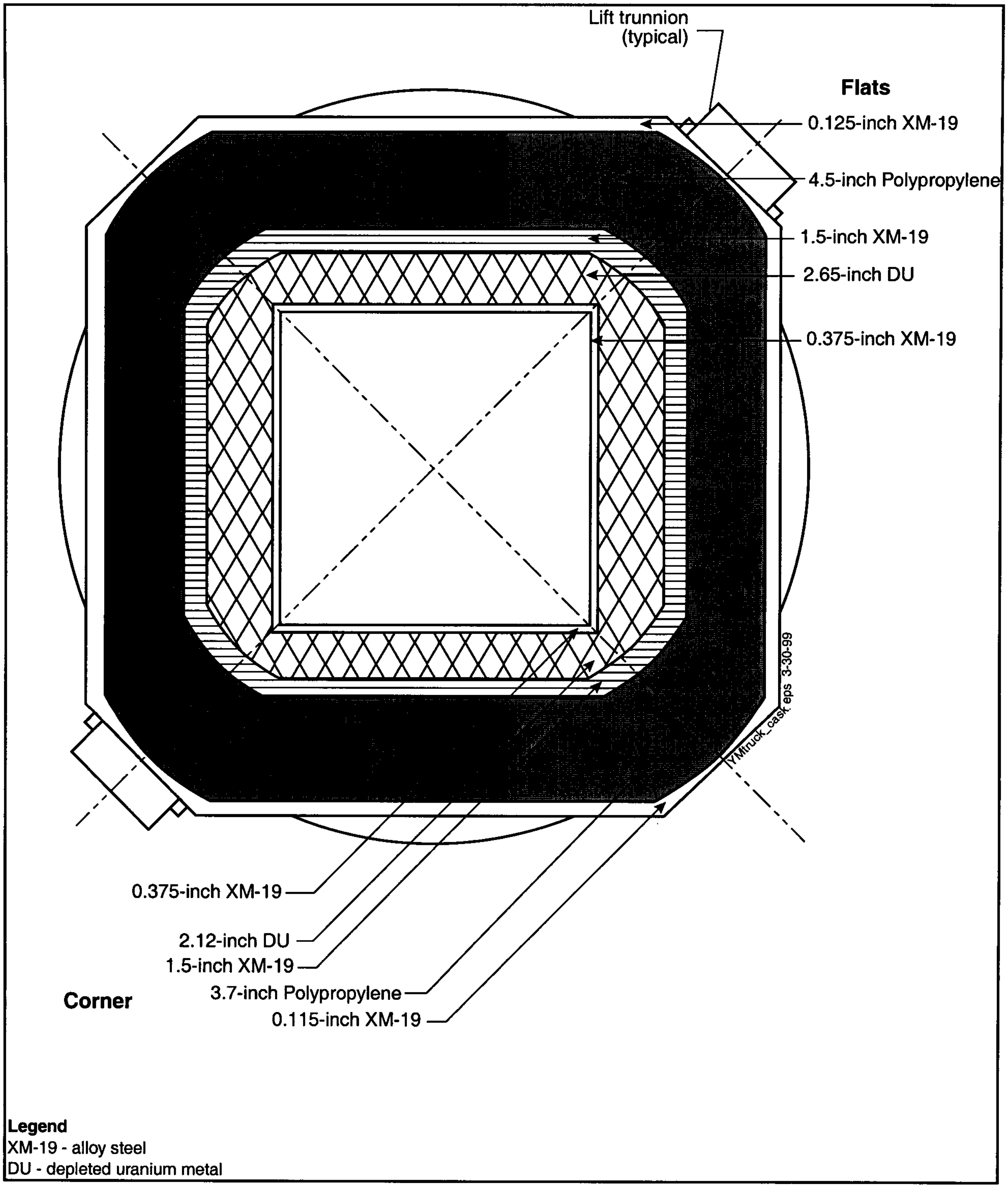

Figure 5-9. Cross sectional drawing of truck cask .

Table 5-64. Results for HEDD1.

	Truck Cask	Rail Cask
Effective diameter of penetration	9.0 cm	7.7 cm
Number of assemblies penetrated	2	2.4
Number of fuel rods disrupted	272	294
Average assembly swept mass	7.3 kg	6.7 kg
Maximum assembly swept mass	9.6 kg	8.7 kg
Average respirable release (without blowdown)	1.7E-2 kg	1.5E-2 kg
Maximum respirable release (without blowdown)	2.2E-2 kg	2.0E-2 kg
Average respirable release fraction (without blowdown)	1.1E-5	1.5E-6
Maximum respirable release fraction (without blowdown)	8.0E-6	1.1E-6
Average respirable release (with blowdown)	2.6E-1 kg	4.2E-2 kg
Maximum respirable release (with blowdown)	3.4E-1 kg	5.5E-2 kg
Average respirable release fraction (with blowdown)	1.2E-4	3.1E-6
Maximum respirable release fraction (with blowdown)	1.6E-4	4.0E-6
Crud release fraction	7.5E-5	1.3E-6
Noble gas release fraction	2.0E-2	4.1E-4
Total volatile release fraction[a]	1.0E-3	1.7E-5
Average nonrespirable release	4.9 kg	4.4 kg
Maximum nonrespirable release	6.4 kg	5.8 kg
Average nonrespirable release fraction	2.3E-3	3.2E-4
Maximum nonrespirable release fraction	3.0E-3	4.2E-4

a. Source: DIRS 104918-Luna, Neuhauser, and Vigil, 1999, all.

Table 5-65. Results for HEDD2.

	Truck Cask	Rail Cask
Effective diameter of penetration	4.1 cm	3.3 cm
Number of assemblies penetrated	2	1.7
Number of fuel rods disrupted	136	90
Average assembly swept mass	1.7 kg	0.87 kg
Maximum assembly swept mass	2.2 kg	1.1 kg
Average respirable release (without blowdown)	3.8E-3 kg	2.0E-3 kg
Maximum respirable release (without blowdown)	5.0E-3 kg	2.6E-3
Average respirable release fraction (without blowdown)	1.8E-6	1.5E-7
Maximum respirable release fraction (without blowdown)	2.4E-6	1.9E-7
Average respirable release (with blowdown)	3.8E-2 kg	3.1E-3 kg
Maximum respirable release (with blowdown)	5.0E-2 kg	4.1E-3 kg
Average respirable release fraction (with blowdown)	1.8E-5	2.3E-7
Maximum respirable release fraction (with blowdown)	2.4E-5	3.0E-7
Crud release fraction	9.1E-6	4.7E-8
Noble gas release fraction	6.2E-3	3.9E-5
Total volatile release fraction[a]	1.4E-4	7.2E-7
Average nonrespirable release	1.1 kg	0.58 kg
Maximum nonrespirable release	1.4 kg	0.76 kg
Average nonrespirable release fraction	5.3E-4	4.3E-5
Maximum nonrespirable release fraction	6.9E-4	5.6E-5

a. Source: DIRS 104918-Luna et al. 1999, all.

Both HEDD1 and HEDD2 were found to penetrate a single wall of the truck and rail casks, but neither HEDD1 nor HEDD2 was found capable of causing penetration completely through both walls of a cask. HEDD1 was found to cause more damage to the casks and SNF than HEDD2. This was because the average diameter of the penetration created by HEDD1 was more than twice as large as the average diameter created by HEDD2, although the penetration depths were about the same for the two devices.

Estimated releases are larger than previously estimated using experimental data (DIRS 156313-Sandoval et al. 1983, all). The larger releases are because the experiments were performed using unpressurized surrogate SNF rods, while the analysis by Luna, Neuhauser, and Vigil (DIRS 104918-1999, all) was based on fuel rods assumed to be pressurized. Release of pressure from the damaged fuel rods, commonly known as blowdown, would result in an additional mechanism for transporting radionuclides from the casks. In the analysis, this blowdown accounts for about 50 percent of the total respirable release from a rail cask, and over 90 percent of the total respirable release from the truck cask. As indicated in Tables 5-64 and 5-65, both respirable (particle size 10 μ (microns) or smaller) and nonrespirable releases were postulated. To calculate consequences due to the nonrespirable fraction using RISKIND, the breathing rate was set to zero and only the direct radiation exposure was modeled. The deposition velocity for the nonrespirable portion (particle size greater than 10 μ) of the released was assumed to be 0.1 meters/sec, which is a factor of 10 greater than that assumed for the respirable portion of the release. See the RISKIND manual (DIRS 101483-Yuan et al, p. G-75) for a discussion of deposition velocity.

Population densities used in consequence analysis. The population densities used to estimate consequences can be found in Section 5.3.3.2 of this calculation package.

Radioactive contents of casks for analyzing consequences of sabotage and terrorism events. The analysis based the calculation of consequences of sabotage and terrorism events on representative PWR SNF described in Attachment 51A of this document. The PWR fuel makes up the largest part of the inventory that would be shipped to the repository under the Proposed Action. Based on the analysis of maximum reasonably foreseeable accidents, the greatest consequences would result from events involving shipments of representative PWR SNF.

The analysis used estimates of releases (cask inventory times release fractions) to the atmosphere as a source term and the RISKIND computer code (DIRS 101483-Yuan et al. 1995, all) to calculate radiological consequences to hypothetical MEIs and populations. The consequences were estimated for rural and urbanized area (urban and suburban areas) populations postulated to live within 80 kilometers (50 miles) of the location of a severe accident.

Postulated atmospheric conditions during severe accidents. Because it is not possible to predict the location or environmental conditions that might exist for acts of sabotage, the analysis determined impacts for urban areas under neutral (average) weather conditions.

Release height. It is expected that for an act of sabotage there would be an initial explosive release involving releases of material at varying release heights. The HOTSPOT Health Physics Code (DIRS 157148-Homann 1994, pp. 7-9 – 7-10) provides the following source distribution for explosion model geometry:

$$\text{Cloud top} = 76\ (w)\ 0.25$$

where:

w = pounds of high explosives, and

The source is distributed as follows:

20% (h=0.8 cloud top)
35% (h = 0.6 cloud top)
25% (h = 0.4 cloud top)
16% (h = 0.2 cloud top)
4% (h = ground level)

Assuming a cloud top of 80 meters (262 feet), the distribution of the source can be easily calculated.

Analysis of impacts to MEIs for sabotage and terrorism events. The Yucca Mountain FEIS also analyzed hypothetical impacts to MEIs for sabotage and terrorism events. The impacts to these individuals were determined by selecting a range of individual locations and implementing these into the RISKIND code to ascertain the location where the dose to an MEI would be the highest.

5.3.4.3 Assumptions

The analysis assumed a cloud top of 80 meters (262 feet) for scenarios associated with both HEDD1 and HEDD2.

Only stability class D conditions with a wind speed of 4.47 meters per second (10 miles per hour) were analyzed for the sabotage and terrorism scenarios.

The deposition velocity for the non-respirable portion (particle size greater than 10 μ (microns)) of the released was assumed to be 0.1 meters/sec, which is a factor of 10 greater than that assumed for the respirable portion of the release.

5.3.4.4 Use of Computer Software and Models

The RISKIND computer program (DIRS 101483-Yuan et al. 1995, all) was used to estimate consequence to the exposed population and to MEI for the sabotage and terrorism scenarios. Further details on the RISKIND code can be found in Section 5.3.3.4.

5.3.4.5 Calculation/Analysis and Results

Consequences of acts of sabotage and terrorism. An act of sabotage would be a single event with an estimated release of radioactive materials from a cask similar to that for a maximum reasonably foreseeable accident. Because of the similarity, the analysis of consequences for a sabotage event used methods (RISKIND computer program) and data that were used to estimate consequences of maximum reasonably foreseeable accidents.

Because it is not possible to estimate the likelihood of a sabotage event, the analysis assumed average (neutral or 50 percent) atmospheric conditions. Estimated amounts and characteristics of releases of radioactive materials from rail and truck casks subjected to attack by two different high-energy density devices are listed in results presented by Sandia National Laboratories (DIRS 104918-Luna, Neuhauser, and Vigil 1999, all). The analysis of maximum reasonably foreseeable accidents assumed an event would occur in an urbanized area, with the distribution of population discussed previously

Tables 5-66 through 5-70 present consequences of releases caused by a sabotage event with two devices identified in the Sandia study (DIRS 104918-Luna, Neuhauser, and Vigil 1999, all). The consequences are presented for (1) each population ring surrounding the postulated location of the event in the center of an urbanized area and (2) each release height for both the respirable and nonrespirable releases. The consequences to MEIs are also presented.

The consequences of an event involving a truck cask are estimated to be greater because of the effects of gas from depressurizing fuel pins failed by the action of a high-energy device. The analysis of the effects of a device (DIRS 104918-Luna, Neuhauser, and Vigil 1999, all) estimated that damage would occur to about two fuel assemblies whether in a rail or a truck cask. A rail cask with a large free volume for gas expansion would release less particulates and gas through a penetration than would a truck cask with a comparatively small free volume available to accommodate approximately the same amount of released gas. Table 5-70 summarizes the sabotage and terrorism results.

The RISKIND input and output files used to estimate the consequences from a terrorist attack on an SNF shipping cask are provided separately in electronic files.

Table 5-66. Sabotage and terrorism results for a legal-weight truck cask – HEDD1.

Sabotage & Terrorism HEDD1 - Respirable					
Ring	20%	35%	25%	16%	4%
letter	64 m	48 m	32 m	16 m	1 m
A	2130	4390	3860	10300	3630
B	492	921	723	2400	593
C	188	351	275	748	191
D	104	194	151	316	85.20
E	60.4	113	88.1	152	40.8
F	135	252	197	259	67.7
TOT	**3109**	**6221**	**5294**	**14175**	**4608**
G	1.31	4.35	7.69	12.800	51.20
Dist.	330	250	160	250	100
Rural	38.5	73.4	57.1	44.4	12.3

Sabotage & Terrorism HEDD1-Nonrespirable					
Ring	20%	35%	25%	16%	4%
letter	64 m	48 m	32 m	16 m	1 m
A	6700	13200	11200	17300	3270
B	1280	2280	1660	974	70.2
C	453	795	570	164	25.6
D	229	401	285	42.3	7.57
E	123	215	150	13.00	2.29
F	235	403	280	8.43	1.29
TOT	**9020**	**17294**	**14145**	**18502**	**3377**
G	0.828	2.59	2.70	8.00	18.2
Dist.	330	250	160	250	100
Rural	39.4	69.4	49.8	31.7	5.3

Table 5-67. Sabotage and terrorism results for a legal-weight truck cask – HEDD2.

Sabotage & Terrorism HEDD2					
Ring	20%	35%	25%	16%	4%
letter	64 m	48 m	32 m	16 m	1 m
A	306	629	553	1470	520
B	70.5	132	104	344	85.0
C	27.0	50.4	39.4	107	27.4
D	14.9	27.8	21.7	45.3	12.2
E	8.66	16.2	12.6	21.7	5.84
F	19.4	36.2	28.2	37.1	9.70
TOT	**446**	**892**	**759**	**2025**	**660**
G	0.187	0.623	1.10	1.83	7.34
Dist.	330	250	160	250	100
Rural	5.52	10.5	8.18	6.33	1.76

Sabotage & Terrorism HEDD2-Nonrespirable					
Ring	20%	35%	25%	16%	4%
letter	64 m	48 m	32 m	16 m	1 m
A	1730	3410	2900	4470	845
B	331	589	429	2520	18.1
C	117	205	147	42.2	6.62
D	59.0	104	73.6	10.9	1.960
E	31.7	55.5	38.8	3.36	0.590
F	60.7	104	72.2	2.18	0.334
TOT	**2329**	**4468**	**3661**	**7049**	**873**
G	0.225	0.751	1.33	2.18	7.28
Dist.	330	250	160	250	100
Rural	10.2	17.9	12.90	8.17	1.370

Table 5-68. Sabotage and terrorism results for a rail cask – HEDD1.

Sabotage & Terrorism HEDD1					
Ring	20%	35%	25%	16%	4%
letter	64 m	48 m	32 m	16 m	1 m
A	300	616	542	1440	510
B	69.0	129	102	338	83.3
C	26.4	49.3	38.6	105	26.8
D	14.6	27.2	21.3	44.4	12.00
E	8.49	15.9	12.4	21.3	5.73
F	19.0	35.5	27.7	36.4	9.50
TOT	**437**	**873**	**744**	**1985**	**647**
G	0.183	0.611	1.08	1.80	7.19
Dist.	340	250	160	260	100
Rural	5.41	10.3	8.02	6.20	1.72
Sabotage & Terrorism HEDD1-Nonrespirable					
Ring	20%	35%	25%	16%	4%
letter	64 m	48 m	32 m	16 m	1 m
A	837	1720	1230	4030	1420
B	193	361	258	943	233
C	73.8	138	98.5	293	74.9
D	40.7	76.0	54.3	124	33.50
E	23.7	44.3	31.6	59.6	16.0
F	53.2	99.1	70.8	102	26.6
TOT	**1221**	**2438**	**1743**	**5552**	**1804**
G	0.513	1.71	3.02	5.03	20.1
Dist.	340	250	160	260	100
Rural	15.1	28.8	20.6	17.3	4.99

Table 5-69. Sabotage and terrorism results for a rail cask – HEDD2.

Sabotage & Terrorism HEDD2					
Ring	20%	35%	25%	16%	4%
letter	64 m	48 m	32 m	16 m	1 m
A	21.1	43.4	38.2	102	35.9
B	4.86	9.11	7.15	23.8	5.87
C	1.86	3.48	2.72	7.40	1.89
D	1.03	1.92	1.50	3.13	0.843
E	0.598	1.12	0.872	1.50	0.403
F	1.34	2.50	1.95	2.56	0.670
TOT	**30.8**	**61.5**	**52.4**	**140**	**45.6**
G	0.0129	0.043	0.0762	0.127	0.507
Dist.	340	250	160	260	100
Rural	0.381	0.727	0.565	0.437	0.121

Sabotage & Terrorism HEDD2-Nonrespirable					
Ring	20%	35%	25%	16%	4%
letter	64 m	48 m	32 m	16 m	1 m
A	113	231	204	542	192
B	25.9	48.6	38.1	127	31.3
C	9.93	18.5	14.5	39.5	10.1
D	5.47	10.2	7.99	16.7	4.50
E	3.19	5.96	4.65	8.01	2.15
F	7.15	13.3	10.4	13.7	3.57
TOT	**165**	**328**	**280**	**747**	**244**
G	6.90E-02	0.23	0.406	0.676	2.7
Dist.	340	250	160	260	100
Rural	2.03	3.88	3.01	2.33	0.671

Table 5-70. Summary of sabotage and terrorism results.

Case	Urban	Rural	MEI
LWT HEDD1 Total (person-rem)	95,745	421	110
LWT HEDD1 Total (LCFs)	48	0.21	0.05
LWT HEDD2 Total (person-rem)	23,161	83	23
LWT HEDD2 Total (LCFs)	12	0.04	0.01
Rail HEDD1 Total (person-rem)	17,445	118	41
Rail HEDD1 Total (LCFs)	9	0.06	0.02
Rail HEDD2 Total (person-rem)	2,093	14	5
Rail HEDD2 Total (LCFs)	1	0.01	0.00

Table 5-71 lists the files found in Attachment 53C.

Table 5-71. Filename key-Attachment 54B.

Case	Case file names	Description
LWT	STTWXYZ.inp	Depleted uranium truck cask RISKIND input file
LWT	DUTXY.out	Depleted uranium truck cask RISKIND output file
Rail	RAILXY.inp	Rail steel-lead-steel cask RISKIND input file
Rail	RAILXY.out	Rail steel-lead-steel cask RISKIND output file
File Names	**Description**	
W	Indicates device HEDD1 or HEDD2 (1 or 2)	
X	Indicates the concentric ring analyzed. (See Table 5-51). Also, A-N. A-F represent stability class D weather conditions and H-M represent stability class F weather conditions G and N represent MEI analysis case	
YZ	Indicates the percentage of the release analyzed as discussed in Section 5.3.4.2.	
*.INP	RISKIND input file	
*.OUT	RISKIND Output File	

6.0 TRANSPORTATION OF MATERIALS, PERSONNEL, AND SITE-GENERATED WASTE

6.1 Introduction

Construction materials, supplies, and a variety of consumables would be transported to the repository site, in addition to the SNF and HLW transported there for disposal. In addition, personnel operating the site would commute to and from the site, and site-generated waste would require removal from the site. This section discusses the health and environmental impacts of these transportation activities. This transportation would have no radiological impact. However, there could be impacts on human health and the environment from the fuel used for transportation and from vehicle exhaust. There could also be traffic fatalities.

The flexible design operating modes used for this analysis are described in detail in the *Scenario/Data Roadmap Calculation/Analysis Documentation in Support of the Final EIS for the Yucca Mountain Respository* (FEIS Roadmap) (DIRS 155522-Jason 2001).

The amount of SNF and HLW transported to the repository would be the same for all of these options, so the selection of any particular option would have no effect on radiological health and safety impacts of transportation. However, the amount of construction materials, the option of a surface aging facility, the number of workers needed for the active life of the repository, and the waste generated at the site would differ for the different options. Consequently, the nonradiological health, safety, and environmental impacts of materials, personnel, and site-generated waste transportation would differ for the seven different options. Impacts of all the different options are considered in this section.

6.2 Method

Calculations for the construction and operation materials needed for the repository, the personnel needed, and the site-generated waste that would need to be carried away are shown in Appendix G. Using the assumptions presented in Section 6.3, the total kilometers traveled, the fuel used, and the health impacts and traffic deaths were calculated. The calculation spreadsheet is Attachment 63A on the compact disk; it shows calculations that are the bases for the tables in Sections 6.3 and 6.5.

6.3 Assumptions

One high-temperature and six lower temperature alternate repository scenarios were analyzed for the Proposed Action. The essential characteristics of these scenarios are provided in Jason (DIRS 155522-2001).

Table 6-1 shows the materials needed for repository construction and operation and the types of site-generated waste, the amount of each material or waste type per shipment, and the distance a shipment of each would travel. Shipments from outside Nevada are assumed to be by rail (amounts are per railcar) and shipments in Nevada are assumed to be by truck. Concrete is assumed to be mixed onsite from cement, sand, and aggregate that are transported from the Las Vegas valley.

Table 6-1. Characteristics of materials shipments for repository construction and of site-generated waste.

Material Transported	Amount per Shipment	Distance Shipped (km)	Description
Materials for Construction and Operation			
Sand and aggregate	22 MT[a]	241.4	Round trip in Nevada
Steel and other metals	20 MT	241.4	Round trip in Nevada
Fuel oil and lubricants	10,000 L[b]	241.4	Round trip in Nevada
Supplies and consumables	NA; data provided as shipments per day	241.4	Round trip in Nevada
Solar cell panels	220	2,065	One way from mid-U.S. site
Waste packages	2 national,[c] 1 in Nevada[d]	4,439	One way from East Coast to Nevada
		1,066	One way in Nevada
Pallets	25 national, 6 in Nevada	2,065	One way from mid-U.S. site
Drip shields	25 national, 5 in Nevada	2,065	One way from mid-U.S. site
Canisters	2	2,065	One way from mid-U.S. site
Liners	6	2,065	One way from mid-U.S. site
Site-Generated Waste			
Construction debris and sanitary industrial waste	84 m^3	120.7	One way in Nevada
Low-level radioactive waste	38 m^3	120.7	One way in Nevada
Hazardous and mixed waste	16.64 m^3	120.7	One way in Nevada
Sanitary sewage and industrial waste water	84 m^3 (84,000 L)	120.7	One way in Nevada

a. MT = metric ton.
b. L = liter.
c. Shipments originate outside Nevada
d. Shipment travels in Nevada by truck from railhead to Yucca Mountain

Table 6-2 summarizes the number of shipments of these materials that would be needed for the Proposed Action.

Table 6-2. Shipments of materials and supplies for the repository for the Proposed Action.[a,b]

Material	High-Temperature Scenarios	Low-Temperature Scenarios: Maximum Spacing – No Aging	Maximum Spacing – Aging	Maximum Ventilation – No Aging	Maximum Ventilation – Aging	Derated Casks	Natural Ventilation
Cement	12,107	23,991	20,410	14,855	18,619	14,323	14,669
Sand/aggregate	18,728	31,910	38,046	23,591	29,637	25,591	23,500
Steel	8,212	14,305	14,866	13,341	5,941	11,850	13,296
Fuel oil/lubricants	39,617	37,810	37,904	42,887	47,700	42,110	41,950
Supplies	271,080	325,296	325,296	777,096	777,096	777,096	777,096
Solar panels	120	97	97	1,314	1,714	1,295	1,194
Waste packages[c]	11,301	11,301	11,301	11,301	11,301	16,884	11,301
Pallets[d]	1,884	1,884	1,884	1,884	1,884	2,814	1,884
Drip shields[e]	2,261	2,261	2,261	2,261	2,261	3,377	2,261
Canisters	0	0	2,238	0	2,238	0	0
Liners	0	0	746	0	746	0	0

a. Source: Spreadsheet in Attachment 63A on compact disk and attached Appendix G.
b. Shipment numbers have been rounded to the next higher whole number.
c. National shipments are 50 percent of these numbers.
d. National shipments are 24 percent of these numbers.
e. National shipments are 20 percent of these numbers.

Table 6-3 summarizes the number of shipments of these materials that will be needed for Modules 1 and 2.

Table 6-4 shows the vehicle distribution for commuting workers estimated for repository construction, operation, and closure. Vehicle use was assumed to be the same as in DIRS 105155 (DOE 1999, pp. J-109-J-110) and is based on the vehicle distribution for 2,000 commuting workers:

Table 6-3. Shipments of materials and supplies for the repository for Modules 1 and 2.[a,b]

Material	High-Temperature Scenarios	Low-Temperature Scenarios: Maximum Spacing – No Aging	Maximum Spacing – Aging	Maximum Ventilation – No Aging	Maximum Ventilation – Aging	Derated Casks	Natural Ventilation
Cement	19,018	23,991	14,850	14,855	19,486	13,455	8,386
Sand/aggregate	37,314	102,932	113,023	49,173	59,264	51,714	49,173
Steel	11,320	23,542	24,142	21,217	21,815	22,752	21,215
Fuel oil/lubricants	109,190	73,900	92,300	73,900	92,300	73,900	73,900
Supplies	271,080	325,296	325,296	777,096	777,096	777,096	777,096
Solar panels	120	97	97	1,314	1,714	1,295	1,194
Waste packages-Mod 1	16,631	16,631	16,631	16,631	16,631	25,354	16,631
Waste packages-Mod 2	17,232	17,232	17,232	17,232	17,232	25,955	17,232
Pallet shipments – Mod 1	2,772	2,772	2,772	2,772	2,772	4,226	2,772
Pallet shipments – Mod 2	2,872	2,872[f]	2,872	2,872	2,872	4,326	2,872
Drip shield shipments-Mod 1	3,326	3,326	3,326	3,326	3,326	5,071	3,326
Drip shield shipments-Mod 2	3,446	3,446	3,446	3,446	3,446	5,191	3,446
Canisters	0	0	2,238	0	2,238	0	0
Liners	0	0	746	0	746	0	0

a. Source: Spreadsheet in Attachment 63A on compact disk and attached Appendix G .
b. Shipment numbers have been rounded to the next higher whole number.
c. National shipments are 50 percent of these numbers.
d. National shipments are 24 percent of these numbers.
e. National shipments are 20 percent of these numbers.

Table 6-4. Types of vehicles and numbers of occupants used in worker commuting.

	For 2,000 Persons	Persons/Vehicle	Numbers and Fractions of Buses, Trucks[a], and Automobiles	
Buses	23	75	Buses+trucks	25.0
One-person cars	152	1	Cars	207.0
Two-person cars	47	2	Total vehicles	232.0
Three+ person cars	8	3	Fraction buses	0.11
Trucks	2	1	Fraction cars	0.89

a. Trucks are counted with buses because they have similar fuel use.

There is an average of 8.6 commuters per vehicle. Further assumptions are:

- Commuters come from, and return to, the Las Vegas area and therefore commute 241 kilometers (150 miles) round-trip each day.
- On the average, workers commute 250 days each year.
- Automobile fuel use is 6.38 kilometers per liter.
- Trucks and buses fuel use is 4.25 kilometers per liter.
- Rail fuel use is 0.0643 kilometers per liter.

Table 6-5 shows the worker-years for each phase of the repository for the Proposed Action.

Table 6-5. Worker-years for Proposed Action.[a]

	Construction	Development/ Emplacement	Monitoring	Closure
High-temperature mode	7,283	41,642	12,354	6,853
Low temperature, maximum spacing, no aging	7,283	43,160	18,203	8,834
Low temperature, maximum spacing, aging	8,003	63,057	15,161	8,834
Low temperature, maximum vent, no aging	7,283	42,280	39,074	7,136
Low temperature, maximum vent, aging	8,003	62,177	36,032	7,136
Low temperature, derated casks	7,439	44,061	38,517	7,419
Low temperature, natural vent, no aging	7,283	42,280	25,074	7,136

a. Source: attached Appendix G

Table 6-6 shows the worker-years for each phase of the repository for Modules 1 and 2.

Table 6-6. Worker-years for Modules 1 and 2.[a]

	Construction	Development/ Emplacement	Monitoring	Closure
High-temperature mode	7,283	65,754	11,151	6,987
Low temperature, maximum spacing, no aging	7,283	66,690	18,842	12,303
Low temperature, maximum spacing, aging	8,002	77,055	17,269	12,303
Low temperature, maximum vent, no aging	7,283	65,754	41,199	8,551
Low temperature, maximum vent, aging	8,002	76,119	39,692	8,551
Low temperature, derated casks	7,439	57,582	40,642	7,728
Low temperature, natural vent, no aging	7,283	65,754	27,949	8,551

a. Source: attached Appendix G.

In addition to materials and worker transportation, waste generated at the site would be transported offsite to southern Nevada. Site-generated waste would include construction debris, sanitary industrial waste, low-level radioactive waste, hazardous and mixed waste, sanitary sewage, and industrial waste water. Low-level radioactive waste would comprise between 3 and 6 percent of the total site-generated waste, and hazardous and mixed waste would comprise between 8 and 16 percent.

Waste would be transported by truck. It is assumed that the waste would only be transported away from the site (121 kilometers [75 miles]). In addition, recyclables from the site are assumed to be transported by the same trucks that carried materials to the site (the round trip has already been accounted for). Tables 6-7, 6-8, and 6-9 show shipments of site-generated waste for the Proposed Action, Module 1, and Module 2, respectively. Calculations to estimate the number of shipments of waste may be found in the spreadsheet of Appendix G and Attachment 63A.

Table 6-7. Site-generated waste shipments for Proposed Action.[a]

	Construction	Development/ Emplacement	Monitoring	Closure
High-temperature mode	3,229	24,823	16,464	5,658
Low temperature, maximum spacing, no aging	3,047	24,139	15,533	7,321
Low temperature, maximum spacing, aging	3,230	23,467	21,479	9,856
Low temperature, maximum vent, no aging	3,077	24,139	39,910	5,838
Low temperature, maximum vent, aging	3,260	23,468	51,734	8,373
Low temperature, derated casks	3,096	25,482	39,041	6,234
Low temperature, natural vent, no aging	3,077	24,139	22,826	5,838

a. Source: attached Appendix G.

Table 6-8. Site-generated waste shipments for Module 1.[a]

	Construction	Development/ Emplacement	Monitoring	Closure
High-temperature mode	2,946	38,457	13,967	6,086
Low temperature, maximum spacing, no aging	3,047	38,538	23,866	9,833
Low temperature, maximum spacing, aging	3,231	37,471	26,773	12,368
Low temperature, maximum vent, no aging	3,077	38,467	27,761	7,112
Low temperature, maximum vent, aging	3,261	37,400	44,769	11,532
Low temperature, derated casks	3,345	48,308	26,652	8,608
Low temperature, natural vent, no aging	3,077	38,467	20,299	7,112

a. Source: attached Appendix G

Table 6-9. Site-generated waste shipments for Module 2.[a]

	Construction	Development/ Emplacement	Monitoring	Closure
High-temperature mode	2,946	39,057	13,958	6,086
Low temperature, maximum spacing, no aging	3,047	39,128	23,866	9,833
Low temperature, maximum spacing, aging	3,231	38,050	26,773	12,368
Low temperature, maximum vent, no aging	3,077	39,057	27,761	7,112
Low temperature, maximum vent, aging	3,261	37,979	30,577	9,645
Low temperature, derated casks	3,362	50,184	26,680	8,720
Low temperature, natural vent, no aging	3,077	39,057	20,299	7,112

a. Source: attached Appendix G.

Other parameters used in the calculation of environmental impacts are the traffic fatality rate (fatal accidents per kilometer of travel) from Saricks and Tompkins (DIRS 103455-1999, Tables 4 and 6), and the emission health effects fatalities per kilometer from exhaust emissions (see Section 4.4 of this calculation package). Values used for traffic fatalities per kilometer were:

For passenger cars and buses: 1×10^{-8} per kilometer (DIRS 104800-CRWMS M&O 1999, Addendum 15)

For trucks: 1.67×10^{-8} per kilometer (DIRS 103455-Saricks and Tompkins 1999, Table 4 for Nevada)

For rail: 7.82×10^{-8} per kilometer (DIRS 103455-Saricks and Tompkins 1999, Table 6, national average)

National average rural, suburban, and urban population densities used to calculate potential fatalities caused by vehicle emissions were estimated using population data for the route from the Comanche Peak (Texas) nuclear power plant to Nevada (see Section 3.0). Clark County and Nye County rural, suburban, and urban population densities were used to calculate potential fatalities caused by vehicle emissions in Nevada, in order to provide a conservative estimate. The following equation was then applied:

$$\text{(ehe fatalities per [person/km}^2\text{] per km.)} \times \text{(persons/km}^2)_{R,\,S,\,U} = \text{ehe fatalities per km}|_{R,S,U}$$

where "ehe fatalities" means exhaust health effect fatalities. Results of the calculation are presented in Table 6-10.

Table 6-10. Calculation of exhaust health effect fatalities (per square kilometer).

	Exhaust Health Effect Fatalities/km[a]	Persons/km²			Exhaust Health Effect Fatalities/km[d]		
		R	S	U	23.R	S	U
Rail	2.60E-11	7.18[b]	708[b]	3,800[b]	1.87E-10	1.84E-08	9.88E-08
Auto	9.40E-12	6.32[c]	741[c]	3,470[c]	5.94E-11	6.97E-09	3.26E-08
Truck	1.50E-11	6.32[c]	741[c]	3,470[c]	9.48E-11	1.11E-08	5.21E-08

a. These numbers are per unit population density.
b. Average population densities along the route from Comanche peak plant to Yucca Mountain.
c. Average population densities in Clark and Nye Counties, Nevada, along the Proposed Action routes to Yucca Mountain.
d. The numbers include population densities (see Attachment 63A).

In addition, the routes were divided into rural, suburban, and urban segments by noting the fractions of the national and Nevada routes from Section 3.0 that were rural, suburban, and urban. Overall, these fractions are:

- National rail routes: 0.922 rural, 0.0669 suburban, 0.0111 urban
- Nevada truck routes: 0.868 rural, 0.119 suburban, 0.0132 urban

Calculation of these fractions is shown in cells C4 to I7 of Attachment 63A.

6.4 Use of Computer Software/Models

A Microsoft® Excel spreadsheet, Attachment 63A on the compact disk, was used to calculate the impacts.

6.5 Calculation/Analysis and Results

The calculations and results for materials transportation, commuter transportation, and site-generated waste transportation are discussed in this section. The complete calculation is included in the spreadsheet in Attachment 63A.

6.5.1 MATERIALS TRANSPORTATION

For materials transportation for each repository phase (construction, emplacement, and monitoring, closure), the following calculations were performed:

- Number of shipments = (units of material)/(units per shipment), where the units are metric tons, liters, cubic meters, etc.

- Number of shipments across the United States to the Nevada state line = waste packages+pallets+solar panels+drip shields+canisters+liners

- Number of shipments in Nevada = waste packages+pallets+solar panels+drip shields+canisters+liners+steel+cement+sand+aggregate+fuel and lubricants

- Kilometers across the United States to the Nevada state line = (waste pkgs) × 4439 km + (other national shipments) × 2,065 km

- Kilometers in Nevada = (waste packages) × 1,066 km + (all other shipments) × 241.4 km

- Total kilometers = national km. + Nevada km.

- Liters of fuel used = (national km)/0.0643 + (Nevada km)/4.25

- Traffic fatalities = (national km) × 7.82×10^{-8}/km + (Nevada km) × 1.67×10^{-8}/km

- Exhaust health effect fatalities = (national km) × $[0.922 \times 1.87 \times 10^{-10} + 0.0669 \times 1.84 \times 10^{-8} + 0.0111 \times 9.88 \times 10^{-8}]$ + (Nevada km) × $[0.868 \times 9.48 \times 10^{-11} + 0.119 \times 1.11 \times 10^{-8} + 0.0132 \times 5.21 \times 10^{-8}]$

The results are shown in Tables 6-11, 6-12, and 6-13 for the Proposed Action.

Table 6-11. Fuel used, in liters, for materials transportation for the Proposed Action.

	Construction	Development/ Emplacement	Monitoring	Closure	Totals
High-temperature mode	2.97E+06	4.28E+08	1.26E+07	2.35E+06	4.46E+08
Low temperature, maximum spacing, no aging	2.90E+06	4.28E+08	1.71E+07	2.24E+06	4.50E+08
Low temperature, maximum spacing, aging	2.89E+06	5.24E+08	1.68E+07	2.24E+06	5.46E+08
Low temperature, maximum vent, no aging	1.03E+07	4.37E+08	5.81E+07	8.10E+06	5.14E+08
Low temperature, maximum vent, aging	1.02E+07	5.41E+08	6.46E+07	7.50E+06	6.23E+08
Low temperature, derated casks	1.00E+07	6.12E+08	5.83E+07	7.49E+06	6.88E+08
Low temperature, natural vent, no aging	1.01E+07	4.37E+08	5.53E+07	7.36E+06	5.10E+08

Table 6-12. Potential traffic fatalities for materials transportation for the Proposed Action.

	Construction	Development/ Emplacement	Monitoring	Closure	Totals
High-temperature mode	0.15	2.68	0.78	0.14	3.76
Low temperature, maximum spacing, no aging	0.17	2.68	1.10	0.14	4.09
Low temperature, maximum spacing, aging	0.17	3.19	1.10	0.14	4.59
Low temperature, maximum vent, no aging	0.21	2.72	2.96	0.17	6.06
Low temperature, maximum vent, aging	0.20	3.30	2.97	0.17	6.65
Low temperature, derated casks	0.19	3.68	2.97	0.17	7.01
Low temperature, natural vent, no aging	0.20	2.72	2.94	0.17	6.03

Table 6-13. Potential emission health effects for materials transportation for the Proposed Action.

	Construction	Development/ Emplacement	Monitoring	Closure	Totals
High-temperature mode	0.019	0.138	0.097	0.018	0.272
Low temperature, maximum spacing, no aging	0.020	0.139	0.137	0.018	0.314
Low temperature, maximum spacing, aging	0.020	0.157	0.138	0.018	0.333
Low temperatu0re, maximum vent, no aging	0.022	0.140	0.362	0.019	0.542
Low temperature, maximum vent, aging	0.022	0.164	0.361	0.019	0.566
Low temperature, derated casks	0.020	0.179	0.364	0.019	0.582
Low temperature, natural vent, no aging	0.022	0.140	0.361	0.018	0.541

Tables 6-14, 6-15, and 6-16 present results for Modules 1 and 2.

Table 6-14. Fuel used, in liters, for materials transportation for Modules 1 and 2.

		Development/Emplacement				Totals	
	Construction	Module 1	Module 2	Monitoring	Closure	Module 1	Module 2
High-temperature mode	2.93E+06	6.28E+08	6.51E+08	1.71E+07	2.38E+06	6.51E+08	6.73E+08
Low temperature, maximum spacing, no aging	2.91E+06	6.27E+08	6.49E+08	2.37E+07	2.25E+06	6.56E+08	6.78E+08
Low temperature, maximum spacing, aging	2.90E+06	7.23E+08	7.46E+08	2.46E+07	2.26E+06	7.53E+08	7.76E+08
Low temperature, maximum vent, no aging	1.03E+07	6.36E+08	6.59E+08	6.19E+07	8.11E+06	7.17E+08	7.39E+08
Low temperature, maximum vent, aging	1.02E+07	7.40E+08	7.62E+08	6.99E+07	7.51E+06	8.27E+08	8.50E+08
Low temperature, derated casks	1.03E+07	9.62E+08	9.85E+08	6.21E+07	7.50E+06	1.04E+09	1.06E+09
Low temperature, natural vent, no aging	1.01E+07	6.36E+08	6.59E+08	5.91E+07	7.39E+06	7.13E+08	7.35E+08

Table 6-15. Potential traffic fatalities for materials transportation for Modules 1 and 2.

		Development/Emplacement				Totals	
	Construction	Module 1	Module 2	Monitoring	Closure	Module 1	Module 2
High-temperature mode	0.15	3.85	4.05	1.10	0.14	5.25	5.37E+00
Low temperature, maximum spacing, no aging	0.17	3.70	3.89	1.57	0.14	4.98	5.09E+00
Low temperature, maximum spacing, aging	0.17	3.59	3.70	1.66	0.14	5.55	5.66E+00
Low temperature, maximum vent, no aging	0.20	3.15	3.47	3.23	0.17	6.76	6.87E+00
Low temperature, maximum vent, aging	0.20	3.67	3.78	3.35	0.17	7.39	7.50E+00
Low temperature, derated casks	0.21	4.78	5.69	3.24	0.17	8.39	8.50E+00
Low temperature, natural vent, no aging	0.20	3.35	3.56	3.21	0.17	6.73	6.85E+00

Table 6-16. Potential emission health effects for materials transportation for Modules 1 and 2.

		Development/Emplacement				Totals	
	Construction	Module 1	Module 2	Monitoring	Closure	Module 1	Module 2
High-temperature mode	0.018	0.192	0.197	0.138	0.018	0.366	0.371
Low temperature, maximum spacing, no aging	0.021	0.183	0.189	0.196	0.018	0.417	0.422
Low temperature, maximum spacing, aging	0.020	0.202	0.207	0.207	0.018	0.447	0.452
Low temperature, maximum vent, no aging	0.022	0.183	0.188	0.396	0.019	0.620	0.625
Low temperature, maximum vent, aging	0.022	0.207	0.212	0.408	0.019	0.655	0.660
Low temperature, derated casks	0.022	0.256	0.261	0.397	0.019	0.694	0.699
Low temperature, natural vent, no aging	0.022	0.183	0.188	0.395	0.019	0.619	0.624

6.5.2 COMMUTER TRANSPORTATION

Fuel use, traffic fatalities, and emission health effects fatalities for commuter transportation were calculated using the equations listed below. The number of FTEs employees is given in Appendix G. The numbers used below have been discussed in Section 6.3.

- Vehicle-years of travel = (worker-years)/(8.6 workers per vehicle)
- Vehicle kilometers = (vehicle years) × (250 trips/year) × (241.4 km/trip)
- Liters of fuel used = (vehicle km)/(0.11 × 4.25 km/liter + 0.89 × 6.38 km/liter)
- Traffic fatalities = (241.4 km) × 1.0×10^{-8}/km
- Exhaust health effect fatalities (241.4) × [$0.868 \times 5.94 \times 10^{-11} + 0.119 \times 6.97 \times 10^{-9} + 0.0132 \times 3.26 \times 10^{-8}$]

Half of the traffic fatalities are estimated to be workers and half to be members of the general public. Tables 6-17, 6-18, and 6-19 present health and safety impacts of worker commuting.

Table 6-17. Fuel used, in liters, for worker commuting for the Proposed Action.

	Construction	Development/ Emplacement	Monitoring	Closure	Totals
High-temperature mode	8.48E+06	4.85E+07	1.44E+07	7.98E+06	7.93E+07
Low temperature, maximum spacing, no aging	8.48E+06	5.02E+07	2.12E+07	1.03E+07	9.02E+07
Low temperature, maximum spacing, aging	9.32E+06	7.34E+07	1.76E+07	1.03E+07	1.11E+08
Low temperature, maximum vent, no aging	8.48E+06	4.92E+07	4.55E+07	8.31E+06	1.11E+08
Low temperature, maximum vent, aging	9.32E+06	7.24E+07	4.19E+07	8.31E+06	1.32E+08
Low temperature, derated casks	8.66E+06	5.13E+07	4.48E+07	8.64E+06	1.13E+08
Low temperature, natural vent, no aging	8.48E+06	4.92E+07	2.92E+07	8.31E+06	9.52E+07

Table 6-18. Potential traffic fatalities for worker commuting for the Proposed Action.

	Construction	Development/ Emplacement	Monitoring	Closure	Totals
High-temperature mode	0.51	2.93	0.87	0.48	4.80
Low temperature, maximum spacing, no aging	0.51	3.04	1.28	0.62	5.46
Low temperature, maximum spacing, aging	0.56	4.44	1.07	0.62	6.70
Low temperature, maximum vent, no aging	0.51	2.98	2.75	0.50	6.75
Low temperature, maximum vent, aging	0.56	4.38	2.54	0.50	7.99
Low temperature, derated casks	0.52	3.10	2.71	0.52	6.86
Low temperature, natural vent, no aging	0.51	2.98	1.77	0.50	5.76

Table 6-19. Potential emission health effects for worker commuting for the Proposed Action.

	Construction	Development/ Emplacement	Monitoring	Closure	Totals
High-temperature mode	0.067	0.385	0.114	0.063	0.63
Low temperature, maximum spacing, no aging	0.067	0.399	0.168	0.082	0.72
Low temperature, maximum spacing, aging	0.074	0.582	0.140	0.082	0.88
Low temperature, maximum vent, no aging	0.067	0.391	0.361	0.066	0.88
Low temperature, maximum vent, aging	0.074	0.574	0.333	0.066	1.05
Low temperature, derated casks	0.069	0.407	0.356	0.069	0.90
Low temperature, natural vent, no aging	0.067	0.391	0.232	0.066	0.76

Tables 6-20, 6-21, and 6-22 present results for Modules 1 and 2.

Table 6-20. Fuel used, in liters, for worker commuting for Modules 1 and 2.

	Construction	Development/ Emplacement	Monitoring	Closure	Totals
High-temperature mode	8.48E+06	7.65E+07	1.30E+07	8.13E+06	1.06E+08
Low temperature, maximum spacing, no aging	8.48E+06	7.76E+07	2.19E+07	1.43E+07	1.22E+08
Low temperature, maximum spacing, aging	9.31E+06	8.97E+07	2.01E+07	1.43E+07	1.33E+08
Low temperature, maximum vent, no aging	8.48E+06	7.65E+07	4.80E+07	9.95E+06	1.43E+08
Low temperature, maximum vent, aging	9.31E+06	8.86E+07	4.62E+07	9.95E+06	1.54E+08
Low temperature, derated casks	8.66E+06	6.70E+07	4.73E+07	9.00E+06	1.32E+08
Low temperature, natural vent, no aging	8.48E+06	7.65E+07	3.25E+07	9.95E+06	1.27E+08

Table 6-21. Potential traffic fatalities for worker commuting for Modules 1 and 2.

	Construction	Development/ Emplacement	Monitoring	Closure	Totals
High-temperature mode	0.51	4.63	0.79	0.49	6.42
Low temperature, maximum spacing, no aging	0.51	4.70	1.33	0.87	7.41
Low temperature, maximum spacing, aging	0.56	5.43	1.22	0.87	8.08
Low temperature, maximum vent, no aging	0.51	4.63	2.90	0.60	8.65
Low temperature, maximum vent, aging	0.56	5.36	2.80	0.60	9.33
Low temperature, derated casks	0.52	4.06	2.86	0.54	7.99
Low temperature, natural vent, no aging	0.51	4.63	1.97	0.60	7.72

Table 6-22. Potential emission health effects for worker commuting for Modules 1 and 2.

	Construction	Development/ Emplacement	Monitoring	Closure	Totals
High-temperature mode	0.067	0.607	0.103	0.065	0.84
Low temperature, maximum spacing, no aging	0.067	0.616	0.174	0.114	0.97
Low temperature, maximum spacing, aging	0.074	0.712	0.160	0.114	1.06
Low temperature, maximum vent, no aging	0.067	0.607	0.381	0.079	1.13
Low temperature, maximum vent, aging	0.074	0.703	0.367	0.079	1.22
Low temperature, derated casks	0.069	0.532	0.375	0.071	1.05
Low temperature, natural vent, no aging	0.067	0.607	0.258	0.079	1.01

6.5.3 SITE-GENERATED WASTE TRANSPORTATION

Health and safety impacts of site-generated waste transportation are calculated in the same way as materials transportation, except that the transportation is assumed to be entirely in Nevada and is one way (from the repository to the Las Vegas valley). This destination does not presume a waste site in the valley; it was chosen because it provides the longest (and thus, the most conservative) reasonable route. Equations used to calculate health impacts are:

- Number of shipments = (units of material)/ (units per shipment), where the units are metric tons, liters, cubic meters, etc.
- Total number of shipments = construction debris + sanitary industrial waste + low-level radioactive waste + hazardous and mixed waste + sanitary sewage + industrial waste water
- Kilometers = (shipments) × 120.7 km
- Liters of fuel used = (kilometers)/4.25 km per liter
- Traffic fatalities = (kilometers) × 1.67×10^{-8}/km
- Exhaust health effect fatalities = (kilometers) × $[0.868 \times 9.48 \times 10^{-11} + 0.119 \times 1.11 \times 10^{-8} + 0.0132 \times 5.21 \times 10^{-8}]$
- Total fatalities = traffic fatalities + exhaust health effect fatalities.

The results are shown in Tables 6-23 to 6-26 for the Proposed Action. Total fuel use is reported, but the potential fatalities attributable to low-level radioactive waste transportation and to hazardous waste transportation are reported separately. In reporting potential fatalities, the emplacement phase of the repository has been combined with the and monitoring phase. Total potential fatalities are reported instead of a breakdown to traffic deaths and exhaust health effects. Calculations are presented in the spreadsheet of Attachment 63A.

Table 6-23. Fuel used, in liters, for site-generated waste transportation for the Proposed Action.

	Construction	Development/ Emplacement	Monitoring	Closure	Totals
High-temperature mode	9.17E+04	7.05E+05	4.68E+05	1.61E+05	1.45E+06
Low temperature, maximum spacing, no aging	8.65E+04	6.86E+05	4.41E+05	2.08E+05	1.42E+06
Low temperature, maximum spacing, aging	9.17E+04	6.66E+05	6.10E+05	2.80E+05	1.65E+06
Low temperature, maximum vent, no aging	8.74E+04	6.86E+05	1.13E+06	1.66E+05	2.07E+06
Low temperature, maximum vent, aging	9.26E+04	6.66E+05	1.47E+06	2.38E+05	2.47E+06
Low temperature, derated casks	8.79E+04	7.24E+05	1.11E+06	1.77E+05	2.10E+06
Low temperature, natural vent, no aging	8.74E+04	6.86E+05	6.48E+05	1.66E+05	1.59E+06

Table 6-24. Potential fatalities for low-level radioactive site-generated waste transportation for the Proposed Action.

	Construction	Development/ Emplacement/ Monitoring	Closure	Totals
High-temperature mode	0.00E+00	5.61E-03	3.58E-04	5.97E-03
Low temperature, maximum spacing, no aging	0.00E+00	4.04E-03	2.06E-04	4.25E-03
Low temperature, maximum spacing, aging	0.00E+00	4.04E-03	1.90E-04	4.23E-03
Low temperature, maximum vent, no aging	0.00E+00	4.04E-03	2.06E-04	4.25E-03
Low temperature, maximum vent, aging	0.00E+00	4.04E-03	1.90E-04	4.23E-03
Low temperature, derated casks	0.00E+00	5.41E-03	2.76E-04	5.69E-03
Low temperature, natural vent, no aging	0.00E+00	4.04E-03	2.06E-04	4.25E-03

Table 6-25. Potential fatalities for hazardous and mixed site-generated waste transportation for the Proposed Action.

	Construction	Development/ Emplacement/ Monitoring	Closure	Totals
High-temperature mode	1.63E-04	8.32E-04	1.59E-04	1.15E-03
Low temperature, maximum spacing, no aging	1.63E-04	8.32E-04	1.59E-04	1.15E-03
Low temperature, maximum spacing, aging	3.10E-04	7.66E-04	1.46E-04	1.22E-03
Low temperature, maximum vent, no aging	1.63E-04	8.32E-04	1.59E-04	1.15E-03
Low temperature, maximum vent, aging	3.10E-04	7.66E-04	1.46E-04	1.22E-03
Low temperature, derated casks	1.70E-04	8.67E-04	1.65E-04	1.20E-03
Low temperature, natural vent, no aging	1.63E-04	8.32E-04	1.59E-04	1.15E-03

Table 6-26. Potential fatalities for transportation of construction debris, sanitary industrial waste, sanitary sewage, and industrial wastewater for the Proposed Action.

	Construction	Development/ Emplacement/ Monitoring	Closure	Totals
High-temperature mode	0.0072	0.087	0.0125	0.107
Low temperature, maximum spacing, no aging	0.0067	0.085	0.0164	0.108
Low temperature, maximum spacing, aging	0.0070	0.097	0.0222	0.126
Low temperature, maximum vent, no aging	0.0068	0.140	0.0130	0.160
Low temperature, maximum vent, aging	0.0071	0.166	0.0188	0.192
Low temperature, derated casks	0.0069	0.140	0.0139	0.161
Low temperature, natural vent, no aging	0.0068	0.102	0.0130	0.121

Tables 6-27 to 6-30 present results for Module 1, and Tables 6-31 to 6-34 present results for Module 2.

Table 6-27. Fuel used, in liters, for site-generated waste transportation for Module 1.

	Construction	Development/ Emplacement	Monitoring	Closure	Totals
High-temperature mode	8.37E+04	1.09E+06	3.97E+05	1.73E+05	1.75E+06
Low temperature, maximum spacing, no aging	8.65E+04	1.09E+06	6.78E+05	2.79E+05	2.14E+06
Low temperature, maximum spacing, aging	9.18E+04	1.06E+06	7.60E+05	3.51E+05	2.27E+06
Low temperature, maximum vent, no aging	8.74E+04	1.09E+06	7.88E+05	2.02E+05	2.17E+06
Low temperature, maximum vent, aging	9.26E+04	1.06E+06	1.27E+06	3.28E+05	2.75E+06
Low temperature, derated casks	9.50E+04	1.37E+06	7.57E+05	2.44E+05	2.47E+06
Low temperature, natural vent, no aging	8.74E+04	1.09E+06	5.76E+05	2.02E+05	1.96E+06

Table 6-28. Potential fatalities for low-level radioactive site-generated waste transportation for Module 1.

	Construction	Development/ Emplacement/Monitoring	Closure	Totals
High-temperature mode	0.00E+00	6.86E-03	2.06E-04	7.07E-03
Low temperature, maximum spacing, no aging	0.00E+00	6.86E-03	2.06E-04	7.07E-03
Low temperature, maximum spacing, aging	0.00E+00	6.86E-03	1.90E-04	7.05E-03
Low temperature, maximum vent, no aging	0.00E+00	6.86E-03	2.06E-04	7.07E-03
Low temperature, maximum vent, aging	0.00E+00	6.86E-03	1.90E-04	7.05E-03
Low temperature, derated casks	0.00E+00	1.67E-02	4.15E-04	1.68E-02
Low temperature, natural vent, no aging	0.00E+00	6.86E-03	2.06E-04	7.07E-03

Table 6-29. Potential fatalities for hazardous and mixed site-generated waste transportation for Module 1.

	Construction	Development/ Emplacement/ Monitoring	Closure	Totals
High-temperature mode	1.63E-04	1.37E-03	1.59E-04	1.69E-03
Low temperature, maximum spacing, no aging	1.63E-04	1.37E-03	1.59E-04	1.69E-03
Low temperature, maximum spacing, aging	3.10E-04	1.26E-03	1.46E-04	1.72E-03
Low temperature, maximum vent, no aging	1.63E-04	1.37E-03	1.59E-04	1.69E-03
Low temperature, maximum vent, aging	3.10E-04	1.26E-03	1.46E-04	1.72E-03
Low temperature, derated casks	2.53E-04	2.15E-03	2.46E-04	2.65E-03
Low temperature, natural vent, no aging	1.63E-04	1.37E-03	1.59E-04	1.69E-03

Table 6-30. Potential fatalities for transportation of construction debris, sanitary industrial waste, sanitary sewage, and industrial wastewater for Module 1.

	Construction	Development/ Emplacement/ Monitoring	Closure	Totals
High-temperature mode	0.0065	0.111	0.0136	0.131
Low temperature, maximum spacing, no aging	0.0067	0.133	0.0221	0.162
Low temperature, maximum spacing, aging	0.0070	0.138	0.0279	0.173
Low temperature, maximum vent, no aging	0.0068	0.142	0.0159	0.165
Low temperature, maximum vent, aging	0.0071	0.178	0.0260	0.211
Low temperature, derated casks	0.0073	0.151	0.0191	0.177
Low temperature, natural vent, no aging	0.0068	0.125	0.0159	0.148

Table 6-31. Fuel used, in liters, for site-generated waste transportation for Module 2.

	Construction	Development/ Emplacement	Monitoring	Closure	Totals
High-temperature mode	8.37E+04	1.11E+06	3.96E+05	1.73E+05	1.76E+06
Low temperature, maximum spacing, no aging	8.65E+04	1.11E+06	6.78E+05	2.79E+05	2.15E+06
Low temperature, maximum spacing, aging	9.18E+04	1.08E+06	7.60E+05	3.51E+05	2.28E+06
Low temperature, maximum vent, no aging	8.74E+04	1.11E+06	7.88E+05	2.02E+05	2.19E+06
Low temperature, maximum vent, aging	9.26E+04	1.08E+06	8.68E+05	2.74E+05	2.31E+06
Low temperature, derated casks	9.55E+04	1.43E+06	7.58E+05	2.48E+05	2.53E+06
Low temperature, natural vent, no aging	8.74E+04	1.11E+06	5.76E+05	2.02E+05	1.98E+06

Table 6-32. Potential fatalities for low-level radioactive site-generated waste transportation for Module 2.

	Construction	Development/ Emplacement/ Monitoring	Closure	Totals
High-temperature mode	0.00E+00	7.89E-03	2.06E-04	8.10E-03
Low temperature, maximum spacing, no aging	0.00E+00	7.89E-03	2.06E-04	8.10E-03
Low temperature, maximum spacing, aging	0.00E+00	7.89E-03	1.90E-04	8.08E-03
Low temperature, maximum vent, no aging	0.00E+00	7.89E-03	2.06E-04	8.10E-03
Low temperature, maximum vent, aging	0.00E+00	7.89E-03	1.90E-04	8.08E-03
Low temperature, derated casks	0.00E+00	1.92E-02	4.25E-04	1.96E-02
Low temperature, natural vent, no aging	0.00E+00	7.89E-03	2.06E-04	8.10E-03

Table 6-33. Potential fatalities for hazardous and mixed site-generated waste transportation for Module 2.

	Construction	Development/ Emplacement/ Monitoring	Closure	Totals
High-temperature mode	1.63E-04	1.68E-03	1.59E-04	0.131
Low temperature, maximum spacing, no aging	1.63E-04	1.68E-03	1.59E-04	0.162
Low temperature, maximum spacing, aging	3.10E-04	1.55E-03	1.46E-04	0.172
Low temperature, maximum vent, no aging	1.63E-04	1.68E-03	1.59E-04	0.165
Low temperature, maximum vent, aging	3.10E-04	1.55E-03	1.46E-04	0.175
Low temperature, derated casks	2.59E-04	2.69E-03	2.52E-04	0.179
Low temperature, natural vent, no aging	1.63E-04	1.68E-03	1.59E-04	0.148

Table 6-34. Potential fatalities for transportation of construction debris, sanitary industrial waste, sanitary sewage, and industrial wastewater for Module 2.

	Construction	Development/ Emplacement/ Monitoring	Closure	Totals
High-temperature mode	0.0065	0.111	0.0136	0.131
Low temperature, maximum spacing, no aging	0.0067	0.133	0.0221	0.162
Low temperature, maximum spacing, aging	0.0070	0.138	0.0279	0.172
Low temperature, maximum vent, no aging	0.0068	0.142	0.0159	0.165
Low temperature, maximum vent, aging	0.0071	0.146	0.0217	0.175
Low temperature, derated casks	0.0074	0.152	0.0194	0.179
Low temperature, natural vent, no aging	0.0068	0.125	0.0159	0.148

7.0 HEALTH AND SAFETY IMPACTS OF SNF AND HLW TRANSPORTATION

7.1 Introduction

This section presents the results of calculations of potential radiological and nonradiological health and safety impacts of transporting SNF and HLW from 72 commercial and 5 DOE sites to the Yucca Mountain site under the Proposed Action, Module 1, and Module 2. National and State of Nevada impacts are considered separately. Collective population impacts are considered, as are the impacts to potential MEIs. Impacts of both incident-free, routine transportation and potential transportation accidents are discussed. Both radiological and nonradiological impacts are considered. This section presents the results of the calculations of radiological and nonradiological health and safety effects.

7.2 Method

Impacts were calculated using the Microsoft® Access database on the accompanying compact disk. The database for the Proposed Action and Modules 1 and 2 is titled "FEIS Transportation 2000." The other databases ("Escorts," "Inspectors," "Truck Spag," and "Truck A –F") deal with the sensitivity of the results to different transportation routes and a variety of assumptions (for example, an inspection at every state border instead of only at the origin and destimation). Appendix A provides considerable detail on this database, including a user guide and a discussion of the interface between the database and RADTRAN. Sections 2.0 through 5.0 of this document describe the inputs to the database, how those inputs were derived, calculated, and structured, and the data sources. Some summary calculations of results were done using an Excel spreadsheet.

7.3 Assumptions

No assumptions were made in this section in addition to those already discussed in Sections 2.0 through 5.0.

7.4 Computer Software and Models

The models described in Sections 2.0 through 5.0 were used for this section. The Microsoft® Access database is available in Access 2000 and can be run on a personal computer, and requires Windows 98, Windows Me, or Windows 2000. The database is available as a read-only file and includes intermediate tables and a list of queries.

7.5 Analysis and Results

Two transportation scenarios are considered in the Proposed Action: the mostly truck scenario and the mostly rail scenario. For these scenarios, there are safety and health impacts associated with incident-free transportation and potential accidents. These impacts are considered separately for national transportation and for transportation in Nevada. In the interest of brevity, all of the results that can be extracted from the Access database are not included in this section. However, a sampling of results is presented.

7.5.1 NATIONAL TRANSPORTATION

Transportation under the mostly truck scenario would be entirely by truck except for the transportation of naval SNF. Under the mostly rail scenario, those sites that have no rail access (that is, the "truck only" sites) would transport by truck. Options are possible for rail transportation for the sites that have no direct rail access and would use heavy-haul trucks for transportation from the origin site to the nearest railhead under the mostly rail scenario: (1) transport by rail to the repository, (2) transfer the cask from rail to heavy-haul truck in Nevada and transport by heavy-haul to the repository, and (3) for sites without rail access that could load a rail cask and that have access to a navigable waterway, transport by barge to a nearby railhead, then transfer of the cask from barge to rail for transportation to the repository. Site access is described in Section 2.0.

7.5.1.1 Proposed Action

For each transportation option, there are incident-free impacts to the off-link and on-link public, members of the public at stops, and transportation workers during transit and at stops. Table 7-1 presents the radiological impacts for national incident-free transportation for the mostly truck scenario of the Proposed Action. The regional corridor routes in Nevada are described in Section 3.1.5. (The doses reported in Table 7-1 do not include loadout.)

The regional corridors are labeled according to Nevada route and transportation mode (for example, Jean Rail). These routes do not include Nevada; however, they enter Nevada at different points so they differ in length and population density. The Nevada designation of these routes is in this section only as an identifier.

Table 7-1. Collective doses in person-rem from national incident-free transportation under the mostly truck scenario-Proposed Action.

Regional Corridor	Off-Link	On-Link	Stops	Public[a]	Worker	Escorts
Apex/Dry Lake Heavy-haul Truck	3.61	3.39	6.61	13.6	16.4	3.70
Apex/Valley Modified Rail	2.80	0.10	6.56	9.46	16.7	2.47
Beowawe/Carlin Rail	0.97	0.09	3.97	5.03	17.0	2.64
Caliente Heavy-haul Truck	2.90	0.79	7.55	11.2	17.1	6.37
Caliente Heavy-haul Truck Chalk Mountain	2.78	0.43	7.54	10.8	16.7	4.22
Caliente Heavy-haul Truck Las Vegas	3.59	4.61	7.59	15.8	16.9	5.02
Caliente Rail	2.78	0.11	6.49	9.38	17.5	2.88
Caliente/Chalk Mountain Rail	2.77	0.10	6.49	9.37	16.8	2.52
Jean Rail	4.93	0.12	9.85	14.9	17.1	2.70
Jean/Sloan Heavy-haul Truck	6.62	3.88	9.94	20.5	16.7	3.94
Truck Sites	873	2506	1629	5008	14096	6.67

a. The public dose is the sum of the off-link, on-link, and stop doses.

In this scenario, there are many more shipments by truck than by rail, thereby accounting for the relatively large contribution of the truck sites. Note that the worker dose (14,095) is almost three times the public dose (5,008).

Table 7-2 presents the radiological impacts for national incident-free transportation for the mostly rail scenario of the Proposed Action, without any barge component.

Table 7-2. Collective doses in person-rem from national incident-free transportation under the mostly rail scenario-Proposed Action.

Regional Corridor	Off-Link	On-Link	Stops	Public[a]	Worker	Escorts
Apex/Dry Lake Heavy-haul Truck	463	127	729	1320	1390	2077
Apex/Valley Modified Rail	439	22.8	731	1193	1401	1886
Beowawe/Carlin Rail	397	22.8	671	1091	1420	1955
Caliente Heavy-haul Truck	439	44.6	756	1240	1417	2524
Caliente Heavy-haul Truck Chalk Mountain	435	33.1	756	1224	1402	2156
Caliente Heavy-haul Truck Las Vegas	461	166	758	1384	1408	2294
Caliente Rail	434	23.2	722	1180	1431	1992
Caliente/Chalk Mountain Rail	434	22.9	722	1179	1408	1909
Jean Rail	496	23.3	816	1335	1414	1932
Jean/Sloan Heavy-haul Truck	549	142	819	1511	1400	2122
Truck Only Sites	22.6	68.3	43.0	134	362	0.17

a. The public dose is the sum of the off-link, on-link, and stop doses.

The mostly rail collective public dose may be compared to the mostly truck collective public dose by adding the largest of the regional corridor public doses, the Jean/Sloan heavy-haul truck dose, to the truck-only dose. The largest mostly truck collective public dose is about three times the largest mostly rail public dose (5,027/1,614 = 3.1) because there are about three times as many truck shipments as rail shipments (see Section 2.0). Moreover, the occupational dose in the mostly truck scenario is about eight times that in the mostly rail scenario, because rail workers receive essentially no radiation dose from the cargo while the train is moving (see Section 4.2).

Table 7-3 presents the incident-free collective doses for the national transportation scenario using barge transport.

Table 7-3. Collective doses in person-rem from national incident-free transportation under the mostly rail scenario including barge transportation.

Regional Corridor	Off-Link	On-Link	Stops	Public[a]	Worker	Escorts
Apex/Dry Lake Heavy-haul Truck	454	120	708	1283	1378	2060
Apex/Valley Modified Rail	430	16.1	710	1156	1389	1870
Beowawe/Carlin Rail	393	16.2	656	1065	1409	1943
Caliente Heavy-haul Truck	430	37.9	735	1202	1405	2508
Caliente Heavy-haul Truck Chalk Mountain	426	26.4	735	1187	1391	2140
Caliente Heavy-haul Truck Las Vegas	452	159	736	1347	1396	2277
Caliente Rail	425	16.5	701	1143	1419	1975
Caliente/Chalk Mountain Rail	425	16.1	701	1142	1396	1893
Jean Rail	487	16.5	795	1298	1402	1916
Jean/Sloan Heavy-haul Truck	540	136	798	1474	1388	2105
Truck Only Sites	22.6	68.3	43.0	134	362	0.17

a. The public dose is the sum of the off-link, on-link, and stop doses.

Radiological accident impacts are called *dose risks* because two probabilities are involved: the probability that the truck will be in an accident and the probability that the accident will be of a particular severity (see Section 5.3). Dose risk is expressed in person-rem, like incident-free doses. Table 7-4 presents the accident impacts for national transportation for the Proposed Action for the different exposure pathways for potentially released radioactive material. Table 7-4 also presents the total dose risk with and without the loss-of-shielding component; worker accident dose risk is included with public accident dose risk. All three transportation scenarios are included in Table 7-4.

Table 7-4. Collective dose risks from potential national transportation accidents for the Proposed Action (1 of 2)

	Regional Corridor	Ground-shine Risk	Immers-ion Risk	Ingest-ion Risk	Inhalat-ion Risk	Resuspens-ion Risk	Dose Risk Without Loss of Shielding	Loss of Shield-ing Risk	Dose Risk Includ-ing Shielding Loss
Mostly Truck	Apex/Dry Lake Heavy-haul Truck	2.64E-05	1.26E-07	5.23E-07	9.87E-07	3.34E-06	3.14E-05	5.12E-04	5.43E-04
	Apex/Valley Modified Rail	1.67E-05	7.97E-08	5.15E-07	6.23E-07	2.11E-06	2.00E-05	3.23E-04	3.43E-04
	Beowawe/Carlin Rail	4.96E-06	2.37E-08	4.52E-07	1.85E-07	6.27E-07	6.25E-06	9.60E-05	1.02E-04
	Caliente Heavy-haul Truck	1.82E-05	8.67E-08	5.41E-07	6.78E-07	2.29E-06	2.18E-05	3.51E-04	3.73E-04
	Caliente Heavy-haul Truck Chalk Mountain	1.67E-05	7.98E-08	5.28E-07	6.24E-07	2.11E-06	2.00E-05	3.23E-04	3.43E-04
	Caliente Heavy-haul Truck Las Vegas	2.64E-05	1.26E-07	5.32E-07	9.87E-07	3.34E-06	3.14E-05	5.12E-04	5.43E-04
	Caliente Rail	1.67E-05	7.96E-08	5.15E-07	6.22E-07	2.11E-06	2.00E-05	3.23E-04	3.43E-04
	Caliente/Chalk Mountain Rail	1.67E-05	7.96E-08	5.15E-07	6.22E-07	2.11E-06	2.00E-05	3.23E-04	3.43E-04
	Jean Rail	1.77E-05	8.46E-08	5.15E-07	6.61E-07	2.24E-06	2.12E-05	3.43E-04	3.64E-04
	Jean/Sloan Heavy-haul Truck	3.81E-05	1.82E-07	5.22E-07	1.42E-06	4.81E-06	4.50E-05	7.37E-04	7.82E-04
	Truck Only Sites	5.23E-02	1.33E-04	1.12E-02	5.98E-03	2.41E-02	0.094	0.369	0.463
Mostly Rail	Apex/Dry Lake Heavy-haul Truck	5.63E-01	7.55E-04	8.34E-02	3.67E-02	1.49E-01	0.833	0.078	0.911
	Apex/Valley Modified Rail	5.26E-01	7.06E-04	8.34E-02	3.43E-02	1.39E-01	0.783	0.073	0.856
	Beowawe/Carlin Rail	4.97E-01	6.70E-04	8.34E-02	3.26E-02	1.32E-01	0.746	0.068	0.813
	Caliente Heavy-haul Truck	5.30E-01	7.10E-04	8.34E-02	3.45E-02	1.40E-01	0.788	0.073	0.862
	Caliente Heavy-haul Truck Chalk Mountain	5.24E-01	7.03E-04	8.33E-02	3.42E-02	1.39E-01	0.781	0.073	0.854
	Caliente Heavy-haul Truck Las Vegas	5.61E-01	7.52E-04	8.33E-02	3.65E-02	1.48E-01	0.830	0.078	0.908
	Caliente Rail	5.24E-01	7.03E-04	8.33E-02	3.41E-02	1.38E-01	0.781	0.073	0.853
	Caliente/Chalk Mountain Rail	5.24E-01	7.03E-04	8.33E-02	3.41E-02	1.38E-01	0.781	0.073	0.853
	Jean Rail	5.36E-01	7.21E-04	7.98E-02	3.51E-02	1.42E-01	0.794	0.074	0.868

Table 7-4. Collective dose risks from potential national transportation accidents for the Proposed Action (2 of 2)

	Regional Corridor	Groundshine Risk	Immersion Risk	Ingestion Risk	Inhalation Risk	Resuspension Risk	Dose Risk Without Loss of Shielding	Loss of Shielding Risk	Dose Risk Including Shielding Loss
	Jean/Sloan Heavy-haul Truck	6.14E-01	8.25E-04	7.99E-02	4.01E-02	1.62E-01	0.898	0.084	0.982
	Truck Only Sites	1.98E-03	6.07E-06	4.65E-04	2.89E-04	1.17E-03	0.004	0.009	0.013
Mostly Rail/ Barge	Apex/Dry Lake Heavy-haul Truck	6.01E-01	9.09E-04	9.90E-02	1.40E-01	6.09E-01	1.450	0.073	1.523
	Apex/Valley Modified Rail	5.64E-01	8.60E-04	9.90E-02	1.38E-01	5.99E-01	1.401	0.068	1.469
	Beowawe/Carlin Rail	5.39E-01	8.30E-04	9.91E-02	1.37E-01	5.94E-01	1.369	0.063	1.432
	Caliente Heavy-haul Truck	5.68E-01	8.64E-04	9.90E-02	1.38E-01	6.00E-01	1.406	0.068	1.474
	Caliente Heavy-haul Truck Chalk Mountain	5.62E-01	8.57E-04	9.90E-02	1.38E-01	5.99E-01	1.398	0.068	1.466
	Caliente Heavy-haul Truck Las Vegas	6.00E-01	9.06E-04	9.90E-02	1.40E-01	6.08E-01	1.448	0.072	1.520
	Caliente Rail	5.62E-01	8.57E-04	9.89E-02	1.38E-01	5.99E-01	1.398	0.068	1.466
	Caliente/Chalk Mountain Rail	5.62E-01	8.57E-04	9.89E-02	1.38E-01	5.99E-01	1.398	0.068	1.47E
	Jean Rail	5.74E-01	8.75E-04	9.55E-02	1.39E-01	6.02E-01	1.412	0.069	1.48E
	Jean/Sloan Heavy-haul Truck	6.52E-01	9.78E-04	9.55E-02	1.44E-01	6.23E-01	1.515	0.079	1.59E
	Truck Only Sites	1.98E-03	6.07E-06	4.65E-04	2.89E-04	1.17E-03	0.0039	0.0094	1.33E-02

Accident dose risks are considerably smaller than incident-free doses because the probability of an accident occurring is about 3×10^{-7} per kilometer, or about 1.2×10^{-3} for a 4, 000-kilometer (2,500-mile) trip (DIRS 103455-Saricks and Tompkins, 1999, Tables 4 and 6). Moreover, the accident dose risk for the mostly truck scenario is dominated by the "loss-of-shielding" component. This dominance occurs because the most likely accident (that is, the accident with a 99.99 percent probability of occurring) is one in which nothing happens to the cargo at all, but the truck or train is stopped in one spot for a considerable period of time. As discussed in Section 5.3.2.3.2, a loss-of-shielding accident model assumes that the vehicle carrying the SNF is immobilized for 12 hours.

An accident that involves a release would have a conditional probability of occurring of less than 10^{-4} (see, for example, Table 5-11), so that the overall probability of such an accident in the mostly truck scenario is about 1×10^{-7} for a 4,000-kilometer (2,500-mile) trip.

7.5.1.2 Modules 1 and 2

As discussed in Sections 2.0 and 3.0, Modules 1 and 2 involve the transportation of additional DOE SNF as well as vitrified waste and GTCC waste. The incident-free doses from national transportation for Module 1 are shown in Tables 7-5, 7-6, and 7-7, and for Module 2 in Tables 7-8, 7-9, and 7-10.

Table 7-5 Collective doses in person-rem from national incident-free transportation under the mostly truck scenario for Module 1.

Regional Corridor	Off-Link	On-Link	Stops	Public	Worker	Escorts
Apex/Dry Lake Heavy-haul Truck	3.61	3.39	6.61	13.61	16.37	3.70
Apex/Valley Modified Rail	2.80	0.10	6.56	9.46	16.70	2.47
Beowawe/Carlin Rail	0.97	0.09	3.97	5.03	16.97	2.64
Caliente Heavy-haul Truck	2.90	0.79	7.55	11.24	17.13	6.37
Caliente Heavy-haul Truck Chalk Mountain	2.78	0.43	7.54	10.75	16.68	4.22
Caliente Heavy-haul Truck Las Vegas	3.59	4.61	7.59	15.80	16.85	5.02
Caliente Rail	2.78	0.11	6.49	9.38	17.49	2.88
Caliente/Chalk Mountain Rail	2.77	0.10	6.49	9.37	16.80	2.52
Jean Rail	4.93	0.12	9.85	14.89	17.12	2.70
Jean/Sloan Heavy-haul Truck	6.62	3.88	9.94	20.45	16.71	3.94
Truck Only Sites	1663	4694	3069	9426	26755	12.5

Table 7-6. Collective doses in person-rem from national incident-free transportation under the mostly rail scenario for Module 1.

Regional Corridor	Off-Link	On-Link	Stops	Public	Worker	Escorts
Apex/Dry Lake Heavy-haul Truck	799	237.7	1272	2309	2580	3711
Apex/Valley Modified Rail	754	40.5	1274	2068	2601	3346
Beowawe/Carlin Rail	672	40.6	1158	1870	2636	3475
Caliente Heavy-haul Truck	755	81.8	1325	2161	2631	4566
Caliente Heavy-haul Truck Chalk Mountain	747	60.0	1325	2132	2603	3862
Caliente Heavy-haul Truck Las Vegas	796	310.9	1328	2435	2614	4126
Caliente Rail	746	41.2	1261	2049	2657	3548
Caliente/Chalk Mountain Rail	746	40.6	1261	2048	2613	3389
Jean Rail	861	41.4	1437	2339	2625	3437
Jean/Sloan Heavy-haul Truck	963	266.6	1442	2672	2599	3799
Truck Only Sites	62.3	190	120	372	1015	0.47

Table 7-7. Collective doses in person-rem from national incident-free transportation under the mostly rail scenario including barge transportation for Module 1.

Regional Corridor	Off-Link	On-Link	Stops	Public	Worker	Escorts
Apex/Dry Lake Heavy-haul Truck	783	225	1234	2241	2561	3679
Apex/Valley Modified Rail	737	27.5	1236	2000	2582	3314
Beowawe/Carlin Rail	668	27.7	1136	1832	2619	3453
Caliente Heavy-haul Truck	738	68.7	1287	2093	2612	4534
Caliente Heavy-haul Truck Chalk Mountain	730	47.0	1286	2064	2584	3830
Caliente Heavy-haul Truck Las Vegas	779	298	1289	2366	2595	4094
Caliente Rail	729	28.2	1222	1980	2638	3515
Caliente/Chalk Mountain Rail	729	27.6	1222	1979	2594	3357
Jean Rail	844	28.4	1398	2271	2606	3404
Jean/Sloan Heavy-haul Truck	946	254	1404	2604	2580	3767
Truck Only Sites	62.3	190	120	372	1015	0.47

Table 7-8. Collective doses in person-rem from national incident-free transportation under the mostly truck scenario for Module 2.

Regional Corridor	Off-Link	On-Link	Stops	Public	Worker	Escorts
Apex/Dry Lake Heavy-haul Truck	4.27	4.01	7.83	16.11	19.37	4.38
Apex/Valley Modified Rail	3.31	0.12	7.77	11.20	19.76	2.93
Beowawe/Carlin Rail	1.15	0.11	4.70	5.96	20.09	3.13
Caliente Heavy-haul Truck	3.43	0.93	8.93	13.30	20.27	7.53
Caliente Heavy-haul Truck Chalk Mountain	3.29	0.50	8.92	12.71	19.74	4.99
Caliente Heavy-haul Truck Las Vegas	4.25	5.46	8.98	18.69	19.94	5.94
Caliente Rail	3.28	0.13	7.68	11.10	20.70	3.41
Caliente/Chalk Mountain Rail	3.28	0.12	7.68	11.08	19.88	2.99
Jean Rail	5.83	0.14	11.65	17.63	20.26	3.19
Jean/Sloan Heavy-haul Truck	7.84	4.59	11.77	24.20	19.77	4.66
Truck Only Sites	1719	4850	3169	9738	27606	13.0

Table 7-9. Collective doses in person-rem from national incident-free transportation under the mostly rail scenario for Module 2.

Regional Corridor	Off-Link	On-Link	Stops	Public	Worker	Escorts
Apex/Dry Lake HH Truck	834	247	1326	2406	2680	3864
Apex/Valley Modified Rail	786	41.9	1328	2156	2702	3486
Beowawe/Carlin Rail	701	41.9	1207	1949	2738	3618
Caliente Heavy-haul Truck	787	84.7	1381	2253	2733	4750
Caliente Heavy-haul Truck Chalk Mountain	780	62.1	1381	2222	2704	4020
Caliente Heavy-haul Truck Las Vegas	830	323	1384	2537	2715	4294
Caliente Rail	779	42.6	1315	2136	2760	3694
Caliente/Chalk Mountain Rail	779	42.0	1314	2135	2714	3531
Jean Rail	898	42.7	1498	2439	2727	3580
Jean/Sloan Heavy-haul Truck	1004	277	1504	2784	2699	3955
Truck Only Sites	62.3	190	120	372	1015	0.47

Table 7-10. Collective doses in person-rem from national incident-free transportation under the mostly rail scenario including barge transportation for Module 2.

Regional Corridor	Off-Link	On-Link	Stops	Public	Worker	Escorts
Apex/Dry Lake Heavy-haul Truck	817	233	1287	2337	2660	3832
Apex/Valley Modified Rail	769	28.7	1289	2087	2682	3454
Beowawe/Carlin Rail	697	28.8	1185	1911	2721	3596
Caliente Heavy-haul Truck	770	71.4	1342	2184	2714	4718
Caliente Heavy-haul Truck Chalk Mountain	763	48.9	1342	2153	2684	3988
Caliente Heavy-haul Truck Las Vegas	813	309	1345	2468	2695	4261
Caliente Rail	762	29.4	1276	2067	2740	3662
Caliente/Chalk Mountain Rail	762	28.8	1275	2066	2695	3498
Jean Rail	881	29.5	1459	2370	2707	3547
Jean/Sloan Heavy-haul Truck	987	263	1465	2715	2680	3923
Truck Only Sites	62.3	190	120	372	1015	0.47

Tables 7-11 and 7-12 present the accident dose risks for all three transportation scenarios for Modules 1 and 2, respectively.

Table 7-11. Accident dose risk in person-rem for national transportation for Module 1.

Scenario	Regional Corridor	Dose Risk	Loss of Shielding Risk	Dose Risk Including Loss of Shielding
Mostly Truck	Apex/Dry Lake Heavy-haul Truck	3.14E-05	5.12E-04	5.43E-04
	Apex/Valley Modified Rail	2.00E-05	3.23E-04	3.43E-04
	Beowawe/Carlin Rail	6.25E-06	9.60E-05	1.02E-04
	Caliente Heavy-haul Truck	2.18E-05	3.51E-04	3.73E-04
	Caliente Heavy-haul Truck Chalk Mountain	2.00E-05	3.23E-04	3.43E-04
	Caliente Heavy-haul Truck Las Vegas	3.14E-05	5.12E-04	5.43E-04
	Caliente Rail	2.00E-05	3.23E-04	3.43E-04
	Caliente/Chalk Mountain Rail	2.00E-05	3.23E-04	3.43E-04
	Jean Rail	2.12E-05	3.43E-04	3.64E-04
	Jean/Sloan Heavy-haul Truck	4.50E-05	7.37E-04	7.82E-04
	Truck Only Sites	0.155	0.685	0.839
Mostly Rail	Apex/Dry Lake Heavy-haul Truck	1.311	0.133	1.444
	Apex/Valley Modified Rail	1.230	0.125	1.354
	Beowawe/Carlin Rail	1.169	0.115	1.284
	Caliente Heavy-haul Truck	1.239	0.126	1.364
	Caliente Heavy-haul Truck Chalk Mountain	1.226	0.124	1.351
	Caliente Heavy-haul Truck Las Vegas	1.308	0.133	1.441
	Caliente Rail	1.226	0.124	1.350
	Caliente/Chalk Mountain Rail	1.226	0.124	1.350
	Jean Rail	1.246	0.127	1.373
	Jean/Sloan Heavy-haul Truck	1.417	0.144	1.561
	Truck Only Sites	0.009	0.026	0.035
Mostly Rail/Barge	Apex/Dry Lake Heavy-haul HH Truck	2.267	0.124	2.390
	Apex/Valley Modified Rail	2.185	0.116	2.301
	Beowawe/Carlin Rail	2.137	0.107	2.243
	Caliente Heavy-haul Truck	2.194	0.117	2.311
	Caliente Heavy-haul Truck Chalk Mountain	2.182	0.115	2.297
	Caliente Heavy-haul Truck Las Vegas	2.263	0.124	2.387
	Caliente Rail	2.182	0.115	2.297
	Caliente/Chalk Mountain Rail	2.182	0.115	2.297
	Jean Rail	2.202	0.118	2.320
	Jean/Sloan Heavy-haul Truck	2.372	0.135	2.507
	Truck Only Sites	0.009	0.026	0.035

Table 7-12. Accident dose risk in person-rem for national transportation for Module 2.

Scenario	Regional Corridor	Dose Risk	Loss of Shielding Risk	Dose Risk Including Loss of Shielding
Mostly Truck	Apex/Dry Lake Heavy-haul Truck	3.72E-05	6.05E-04	6.43E-04
	Apex/Valley Modified Rail	2.37E-05	3.82E-04	4.06E-04
	Beowawe/Carlin Rail	7.39E-06	1.14E-04	1.21E-04
	Caliente Heavy-haul Truck	2.57E-05	4.16E-04	4.42E-04
	Caliente Heavy-haul Truck Chalk Mountain	2.37E-05	3.83E-04	4.06E-04
	Caliente Heavy-haul Truck Las Vegas	3.72E-05	6.06E-04	6.43E-04
	Caliente Rail	2.36E-05	3.82E-04	4.05E-04
	Caliente/Chalk Mountain Rail	2.36E-05	3.82E-04	4.05E-04
	Jean Rail	2.51E-05	4.06E-04	4.31E-04
	Jean/Sloan Heavy-haul Truck	5.32E-05	8.72E-04	9.25E-04
	Truck Only Sites	0.155	0.711	0.866
Mostly Rail	Apex/Dry Lake Heavy-haul Truck	1.311	0.137	1.448
	Apex/Valley Modified Rail	1.230	0.129	1.358
	Beowawe/Carlin Rail	1.169	0.118	1.288
	Caliente Heavy-haul Truck	1.239	0.130	1.368
	Caliente Heavy-haul Truck Chalk Mountain	1.226	0.128	1.355
	Caliente Heavy-haul Truck Las Vegas	1.308	0.137	1.445
	Caliente Rail	1.226	0.128	1.355
	Caliente/Chalk Mountain Rail	1.226	0.128	1.355
	Jean Rail	1.246	0.131	1.378
	Jean/Sloan Heavy-haul Truck	1.417	0.149	1.566
	Truck Only Sites	0.009	0.026	0.035
Mostly Rail/Barge	Apex/Dry Lake Heavy-haul Truck	2.267	0.128	2.395
	Apex/Valley Modified Rail	2.185	0.119	2.305
	Beowawe/Carlin Rail	2.137	0.110	2.247
	Caliente Heavy-haul Truck	2.194	0.120	2.315
	Caliente Heavy-haul Truck Chalk Mountain	2.182	0.119	2.301
	Caliente Heavy-haul Truck Las Vegas	2.264	0.128	2.391
	Caliente Rail	2.182	0.119	2.301
	Caliente/Chalk Mountain Rail	2.182	0.119	2.301
	Jean Rail	2.202	0.122	2.324
	Jean/Sloan Heavy-haul Truck	2.372	0.140	2.512
	Truck Only Sites	0.009	0.026	0.035

7.5.1.3 Summary

In accordance with the recommendations of DIRS 101836 (ICRP 1991, p.70, Table S-3), potential LCFs may be estimated by multiplying the dose (or dose risk) in person-rem by 0.0005 LCF per person-rem for public exposure and by 0.0004 LCF per person-rem for occupational exposure. Table 7-13 presents these estimates for both accident and incident-free exposures for the Proposed Action for the mostly truck case, and Table 7-14 presents this information for the Proposed Action for the mostly rail case. LCFs are calculated as follows:

For incident-free transportation:

Public dose (person-rem) × 0.0005 LCF/person-rem = Public LCF
Worker dose (person-rem) × 0.0004 LCF/person-rem = Worker LCF
Escort dose (person-rem) × 0.0004 LCF/person-rem = Escort LCF

For potential transportation accidents:

Total dose risk (person-rem) × 0.0005 LCF/person-rem = LCF
Loss of shielding dose risk is included in the accident dose risk.

Tables 7-13 and 7-14 also present potential LCFs from inhaling vehicle emissions (see Section 4.4) and potential traffic fatalities associated with trucks and rail cars (DIRS 103455-Saricks and Tompkins, 1999, Tables 4 and 6). The calculation of vehicle emission-related health effects is discussed in Section 4.4. Traffic fatalities are calculated by multiplying the traffic fatalities per kilometer (DIRS 103455-Saricks and Tompkins, 1999) by the total kilometers traveled.

Tables 7-13 and 7-14 allow comparisons between radiological and nonradiological, incident-free health impacts, by comparing incident-free LCFs with pollution health impacts. The tables also allow comparisons between radiological and nonradiological accident impacts, by comparing accident LCFs with traffic deaths.

Table 7-13. Potential LCFs from radiological exposure and pollution health effects and traffic fatalities in national transportation, both incident-free and potential accidents, for the mostly truck scenario for the Proposed Action.

Regional Corridor	Public Incident-free LCF	Worker Incident-free LCF	Accident LCF	Pollution Health Effects	Traffic Deaths
Apex/Dry Lake Heavy-haul Truck	0.00681	0.000803	2.71E-07	0.000548	0.0313
Apex/Valley Modified Rail	0.00473	0.000767	1.71E-07	0.000350	0.0245
Beowawe/Carlin Rail	0.00252	0.000785	5.11E-08	0.000138	0.0155
Caliente Heavy-haul Truck	0.00562	0.000940	1.87E-07	0.000376	0.0448
Caliente Heavy-haul Truck Chalk Mountain	0.00537	0.000836	1.72E-07	0.000347	0.0347
Caliente Heavy-haul Truck Las Vegas	0.00790	0.000875	2.72E-07	0.000545	0.0385
Caliente Rail	0.00469	0.000815	1.71E-07	0.000346	0.0251
Caliente/Chalk Mountain Rail	0.00468	0.000773	1.71E-07	0.000346	0.0246
Jean Rail	0.00745	0.000793	1.84E-07	0.000321	0.0248
Jean/Sloan Heavy-haul Truck	0.0102	0.000826	3.93E-07	0.0103	0.0318
Truck Only Sites	2.50	5.64	2.32E-04	0.93	4.47

Table 7-14. Potential LCFs from radiological exposure and pollution health effects and traffic fatalities in national transportation, both incident-free and potential accidents, for the mostly rail scenario for the Proposed Action.

Regional Corridor	Public Incident-free LCF	Worker Incident-free LCF	Accident LCF	Pollution Health Effects	Traffic Deaths
Apex/Dry Lake Heavy-haul Truck	0.660	1.39	4.55E-04	0.608	2.646
Apex/Valley Modified Rail	0.596	1.31	4.28E-04	0.555	2.465
Beowawe/Carlin Rail	0.545	1.35	4.07E-04	0.506	2.217
Caliente Heavy-haul Truck	0.620	1.58	4.31E-04	0.557	3.015
Caliente Heavy-haul Truck Chalk Mountain	0.612	1.42	4.27E-04	0.549	2.739
Caliente Heavy-haul Truck Las Vegas	0.692	1.48	4.54E-04	0.605	2.842
Caliente Rail	0.590	1.37	4.27E-04	0.548	2.479
Caliente/Chalk Mountain Rail	0.590	1.33	4.27E-04	0.548	2.462
Jean Rail	0.667	1.34	4.34E-04	0.626	2.553
Jean/Sloan Heavy-haul Truck	0.755	1.41	4.91E-04	0.743	2.743
Truck Only Sites	0.067	0.144	6.65E-06	0.024	0.116

7.5.2 NEVADA TRANSPORTATION

The discussion of health and safety impacts in this section applies to transportation within Nevada.

7.5.2.1 Proposed Action: Nevada

Tables 7-15 and 7-16 present the incident-free doses for Nevada transportation for the Proposed Action for the mostly truck and mostly rail scenarios, respectively. Transportation by legal-weight truck through Nevada to the repository (the row in Tables 7-15 and 7-16 labeled "Nevada to Repository: Truck") does not include an escort dose except for the second crew member in the vehicle because the analysis assumed that trucks would not be escorted except in urban, heavily populated areas. The alternate routes through Nevada that are included in the sensitivity cases (Truck Spag, Truck A, Truck B, etc.), which could include heavily populated areas, would involve escorts through any urban areas.

Table 7-15. Collective doses in person-rem from Nevada incident-free transportation for the Proposed Action under the mostly truck scenario.

Corridor	Off-Link	On-Link	Stops	Public	Worker	Escorts
Apex/Dry Lake Heavy-haul Truck	0.834	3.313	0.125	4.272	7.107	2.036
Apex/Valley Modified Rail	0.021	0.024	0.075	0.120	7.439	0.807
Beowawe/Carlin Rail	0.261	0.052	0.533	0.846	9.108	1.667
Caliente Heavy-haul Truck	0.126	0.710	1.059	1.895	7.868	4.698
Caliente Heavy-haul Truck Chalk Mountain	0.004	0.347	1.051	1.403	7.424	2.551
Caliente Heavy-haul Truck Las Vegas	0.818	4.532	1.103	6.454	7.590	3.355
Caliente Rail	0.0023	0.035	0.003	0.039	8.230	1.213
Caliente/Chalk Mountain Rail	0.0011	0.025	0.000	0.025	7.537	0.857
Jean Rail	2.152	0.041	3.359	5.552	7.862	1.029
Jean/Sloan Heavy-haul Truck	3.849	3.802	3.455	11.11	7.450	2.268
Nevada to Repository	90.0	123	127	340	1863	0.000

Table 7-16. Collective doses in person-rem from Nevada incident-free transportation for the Proposed Action under the mostly rail scenario.

Corridor	Off-Link	On-Link	Stops	Public	Worker	Escorts
Apex/Dry Lake Heavy-haul Truck	31.7	105	12	149	480	374
Apex/Valley Modified Rail	6.97	0.77	12.0	19.8	491	183
Beowawe/Carlin Rail	10.1	1.70	19.9	31.7	550	391
Caliente Heavy-haul Truck	8.67	22.6	40.9	72.1	507	821
Caliente Heavy-haul Truck Chalk Mountain	4.82	11.1	40.6	56.5	492	453
Caliente Heavy-haul Truck Las Vegas	30.6	144	42.3	217	498	591
Caliente Rail	4.26	1.15	6.62	12.0	521	288
Caliente/Chalk Mountain Rail	4.22	0.83	6.53	11.6	497	206
Jean Rail	58.1	1.17	90.4	150	501	220
Jean/Sloan Heavy-haul Truck	112	120	93.5	326	487	409
Nevada to Repository	1.66	2.45	2.60	6.71	38.42	0.00

Table 7-17 shows the accident dose risks for Nevada transportation for the Proposed Action for both the mostly truck and mostly rail scenarios.

Table 7-17. Collective dose risks from potential Nevada transportation accidents for the Proposed Action, showing the dose risk for each exposure pathway.

	Regional Corridor	Groundshine Risk	Immersion Risk	Ingestion Risk	Inhalation Risk	Resuspension Risk	Dose Risk Without Loss of Shielding	Loss of Shielding Risk	Dose Risk Including Shielding Loss
Mostly Truck	Apex/Dry Lake Heavy-haul Truck	9.76E-06	4.66E-08	9.36E-09	3.65E-07	1.23E-06	1.14E-05	1.89E-04	2.00E-04
	Apex/Valley Modified Rail	1.78E-08	8.49E-11	1.27E-09	6.64E-10	2.25E-09	2.20E-08	3.44E-07	3.66E-07
	Beowawe/ Carlin Rail	2.04E-07	9.75E-10	2.59E-09	7.62E-09	2.58E-08	2.41E-07	3.95E-06	4.19E-06
	Caliente Heavy-haul Truck	1.49E-06	7.13E-09	2.81E-08	5.58E-08	1.89E-07	1.77E-06	2.89E-05	3.07E-05
	Caliente Heavy-haul Truck Chalk Mountain	3.93E-08	1.88E-10	1.51E-08	1.47E-09	4.97E-09	6.10E-08	7.61E-07	8.22E-07
	Caliente Heavy-haul Truck Las Vegas	9.78E-06	4.67E-08	1.90E-08	3.65E-07	1.24E-06	1.14E-05	1.89E-04	2.01E-04
	Caliente Rail	1.29E-09	6.15E-12	1.92E-09	4.81E-11	1.63E-10	3.42E-09	2.49E-08	2.84E-08
	Caliente/Chalk Mountain Rail	1.31E-10	6.27E-13	1.35E-09	4.90E-12	1.66E-11	1.51E-09	2.54E-09	4.05E-09
	Jean Rail	1.28E-06	6.11E-09	1.54E-09	4.77E-08	1.62E-07	1.49E-06	2.47E-05	2.62E-05
	Jean/Sloan Heavy-haul Truck	2.16E-05	1.03E-07	8.74E-09	8.08E-07	2.74E-06	2.53E-05	4.19E-04	4.44E-04
	Nevada to Repository	6.36E-03	1.64E-05	5.32E-06	7.41E-04	2.99E-03	1.01E-02	4.20E-02	5.21E-02
Mostly Rail	Apex/Dry Lake Heavy-haul Truck	3.80E-02	5.02E-05	2.80E-05	2.43E-03	9.85E-03	5.04E-02	4.85E-03	5.52E-02
	Apex/Valley Modified Rail	6.65E-04	1.00E-06	3.84E-06	5.02E-05	2.05E-04	9.25E-04	8.43E-05	1.01E-03
	Beowawe/Carlin Rail	1.04E-03	1.42E-06	8.33E-06	6.94E-05	2.82E-04	1.40E-03	1.51E-04	1.55E-03
	Caliente Heavy-haul Truck	6.20E-03	8.30E-06	8.44E-05	4.03E-04	1.63E-03	8.33E-03	7.86E-04	9.12E-03
	Caliente Heavy-haul Truck Chalk Mountain	6.16E-04	9.34E-07	4.55E-05	4.69E-05	1.91E-04	9.01E-04	7.42E-05	9.75E-04
	Caliente Heavy-haul Truck Las Vegas	3.80E-02	5.03E-05	5.72E-05	2.43E-03	9.85E-03	5.04E-02	4.85E-03	5.53E-02
	Caliente Rail	4.28E-04	6.74E-07	6.26E-06	3.42E-05	1.40E-04	6.09E-04	5.02E-05	6.59E-04
	Caliente/Chalk Mountain Rail	4.24E-04	6.68E-07	4.48E-06	3.39E-05	1.38E-04	6.01E-04	4.95E-05	6.50E-04
	Jean Rail	4.09E-03	5.36E-06	4.33E-06	2.59E-04	1.05E-03	5.41E-03	6.79E-04	6.09E-03
	Jean/Sloan Heavy-haul Truck	8.23E-02	1.08E-04	2.58E-05	5.24E-03	2.12E-02	1.09E-01	1.07E-02	1.20E-01
	Nevada to Repository	1.63E-04	4.93E-07	1.72E-07	2.34E-05	9.49E-05	2.82E-04	7.75E-04	1.06E-03

7.5.2.2 Modules 1 and 2: Nevada

Tables 7-18 and 7-19 present the incident-free collective off-link, on-link, and stop doses for Nevada transportation for Module 1 and the collective public, worker, and escort doses for Modules 1 and 2, for the mostly truck and mostly rail scenarios, respectively.

Table 7-18 Collective doses in person-rem from Nevada incident-free transportation for Modules 1 and 2 under the mostly truck scenario.

	Module 1[a]						Module 2		
Corridor	Off Link	On Link	Stops	Total Public	Worker	Escorts	Total Public	Worker	Escorts
Apex/Dry Lake Heavy-haul Truck	0.834	3.313	0.125	4.272	7.11	2.04	5.06	8.41	2.41
Apex/Valley Modified Rail	0.021	0.024	0.075	0.120	7.44	0.81	0.14	8.80	0.96
Beowawe/Carlin Rail	0.261	0.052	0.533	0.846	9.11	1.67	1.00	10.78	1.97
Caliente Heavy-haul Truck	0.126	0.710	1.059	1.895	7.87	4.70	2.24	9.31	5.56
Caliente Heavy-haul Truck Chalk Mountain	0.004	0.347	1.051	1.403	7.424	2.55	1.66	8.78	3.02
Caliente Heavy-haul Truck Las Vegas	0.818	4.532	1.103	6.454	7.590	3.347	7.637	8.982	3.970
Caliente Rail	0.0014	0.035	0.0034	0.039	8.23	1.21	0.047	9.74	1.44
Caliente/Chalk Mountain Rail	0.0001	0.025	0.0004	0.025	7.54	0.86	0.030	8.92	1.01
Jean Rail	2.15	0.041	3.36	5.55	7.86	1.03	6.57	9.30	1.22
Jean/Sloan Heavy-haul Truck	3.85	3.80	3.45	11.11	7.45	2.27	13.14	8.82	2.68
Nevada to Repository	181	247	253	682	3728	0.00	700	3829	0.00

a. There is little difference between the values in these columns and the corresponding values for Module 2. Therefore the values for Module 2 are not cited

Table 7-19. Collective doses in person-rem from Nevada incident-free transportation for Modules 1 and 2 under the mostly rail scenario.

	Module 1[a]						Module 2		
Corridor	Off Link	On Link	Stops	Total Public	Worker	Escorts	Total Public	Worker	Escorts
Apex/Dry Lake Heavy-haul Truck	59.3	199	21.7	280	915	716	290	948	742
Apex/Valley Modified Rail	12.3	1.45	21.3	35.0	936	350	36.0	970	363
Beowawe/Carlin Rail	18.9	3.22	37.5	59.6	1047	749	61.8	1086	776
Caliente Heavy-haul Truck	16.1	42.7	76.8	136	966	1571	141	1002	1628
Caliente Heavy-haul Truck Chalk Mountain	6.76	20.94	73.91	101.61	938.24	862.39	105.25	972.61	893.25
Caliente Heavy-haul Truck Las Vegas	57.6	272	79.5	409	949	1131	424	984	1171
Caliente Rail	8.00	2.17	12.4	22.6	992	552	23.2	1029	572
Caliente/Chalk Mountain Rail	7.92	1.56	12.2	21.7	948	394	22.3	983	408
Jean Rail	110	2.22	171	283	955	422	294	990	437
Jean/Sloan Heavy-haul Truck	211	227	177	616	928	784	640	962	813
Nevada to Repository	4.80	7.10	7.52	19.41	111.17	0.00	19.41	111.17	0.00

Table 7-20 presents the accident dose risk for Nevada transportation for Modules 1 and 2. Dose risks for each exposure pathway are presented here only for Module 1, because there is so little difference between the risks for Modules 1 and 2.

The database presents the results for both Modules 1 and 2. Total accident dose risks are presented in a single table, Table 7-20, because there is little difference between the results for Modules 1 and 2.

7.5.2.3 Summary: Nevada

In accordance with the recommendations of 101836 (ICRP 1991, p.70, Table S-3), LCFs may be estimated by multiplying the dose (or dose risk) in person-rem by 0.0005 LCF per person-rem for public exposure and by 0.0004 LCF per person-rem for occupational exposure. Table 7-21 presents these estimates for both accident and incident-free exposures for the Proposed Action for Nevada for the mostly truck case, and Table 7-22 presents this information for the Proposed Action for Nevada for the mostly rail case. LCFs are calculated as shown in Section 7.5.1.3. Escort risks are included in these tables for Nevada because they are significant fractions of the total occupational risk.

Tables 7-21 and 7-22 also present potential LCFs from inhaling vehicle emissions (see Section 4.4.5) and potential traffic fatalities associated with trucks and rail cars (103455-Saricks and Tompkins, 1999, Tables 4 and 6). The calculation of vehicle emission-related health effects is discussed in Section 4.4.5. Table 7-23 presents traffic fatalities for the alternative routes in the Proposed Action. Traffic fatality rates for the State of Nevada are used in this calculation. Traffic fatalities are calculated by multiplying the traffic fatalities per kilometer (DIRS 103455- Saricks and Tompkins 1999, Tables 4 and 6), by the total kilometers traveled.

Table 7-20. Collective dose risks from potential Nevada transportation accidents for Modules 1 and 2, showing the dose risk for each exposure pathway.

	Regional Corridor	Module 1								Module 2	
		Groundshine Risk	Immersion Risk	Ingestion Risk	Inhalation Risk	Resuspension Risk	Dose Risk Without Loss of Shielding	Loss of Shielding Risk	Dose Risk Including Shielding Loss	Dose Risk Without Loss of Shielding	Dose Risk Including Shielding Loss
Mostly Truck	Apex/Dry Lake Heavy-haul Truck	9.76E-06	4.66E-08	9.36E-09	3.65E-07	1.23E-06	1.14E-05	1.89E-04	2.00E-04	1.35E-05	2.37E-04
	Apex/Valley Modified Rail	1.78E-08	8.49E-11	1.27E-09	6.64E-10	2.25E-09	2.20E-08	3.44E-07	3.66E-07	2.61E-08	4.33E-07
	Beowawe/ Carlin Rail	2.04E-07	9.75E-10	2.59E-09	7.62E-09	2.58E-08	2.41E-07	3.95E-06	4.19E-06	2.85E-07	4.96E-06
	Caliente Heavy-haul Truck	1.49E-06	7.13E-09	2.81E-08	5.58E-08	1.89E-07	1.77E-06	2.89E-05	3.07E-05	2.10E-06	3.63E-05
	Caliente Heavy-haul Truck Chalk Mountain	3.93E-08	1.88E-10	1.51E-08	1.47E-09	4.97E-09	6.10E-08	7.61E-07	8.22E-07	7.22E-08	9.72E-07
	Caliente Heavy-haul Truck Las Vegas	9.78E-06	4.67E-08	1.90E-08	3.65E-07	1.24E-06	1.14E-05	1.89E-04	2.01E-04	1.35E-05	2.38E-04
	Caliente Rail	1.29E-09	6.15E-12	1.92E-09	4.81E-11	1.63E-10	3.42E-09	2.49E-08	2.84E-08	4.05E-09	3.36E-08
	Caliente/Chalk Mountain Rail	1.31E-10	6.27E-13	1.35E-09	4.90E-12	1.66E-11	1.51E-09	2.54E-09	4.05E-09	1.78E-09	4.79E-09
	Jean Rail	1.28E-06	6.11E-09	1.54E-09	4.77E-08	1.62E-07	1.49E-06	2.47E-05	2.62E-05	1.77E-06	3.10E-05
	Jean/Sloan Heavy-haul Truck	2.16E-05	1.03E-07	8.74E-09	8.08E-07	2.74E-06	2.53E-05	4.19E-04	4.44E-04	2.99E-05	5.26E-04
	Nevada to Repository	1.06E-02	2.73E-05	8.73E-06	1.23E-03	4.96E-03	1.01E-02	4.20E-02	5.21E-02	1.68E-02	1.04E-01
Mostly Rail	Apex/Dry Lake Heavy-haul Truck	6.25E-02	8.25E-05	4.58E-05	3.98E-03	1.61E-02	5.04E-02	4.85E-03	5.52E-02	8.28E-02	9.14E-02
	Apex/Valley Modified Rail	1.13E-03	1.70E-06	6.24E-06	8.54E-05	3.49E-04	9.25E-04	8.43E-05	1.01E-03	1.57E-03	1.72E-03
	Beowawe/Carlin Rail	1.70E-03	2.32E-06	1.36E-05	1.14E-04	4.61E-04	1.40E-03	1.51E-04	1.55E-03	2.29E-03	2.58E-03
	Caliente Heavy-haul Truck	1.02E-02	1.37E-05	1.38E-04	6.63E-04	2.69E-03	8.33E-03	7.86E-04	9.12E-03	1.37E-02	1.51E-02
	Caliente Heavy-haul Truck Chalk Mountain	1.04E-03	1.59E-06	7.46E-05	7.97E-05	3.25E-04	9.01E-04	7.42E-05	9.75E-04	1.53E-03	1.66E-03
	Caliente Heavy-haul Truck Las Vegas	6.26E-02	8.25E-05	9.38E-05	3.99E-03	1.62E-02	5.04E-02	4.85E-03	5.53E-02	8.29E-02	9.15E-02
	Caliente Rail	7.41E-04	1.17E-06	1.02E-05	5.93E-05	2.42E-04	6.09E-04	5.02E-05	6.59E-04	1.05E-03	1.15E-03
	Caliente/Chalk Mountain Rail	7.33E-04	1.16E-06	7.31E-06	5.88E-05	2.40E-04	6.01E-04	4.95E-05	6.50E-04	1.04E-03	1.14E-03
	Jean Rail	6.58E-03	8.60E-06	7.00E-06	4.15E-04	1.68E-03	5.41E-03	6.79E-04	6.09E-03	8.69E-03	1.00E-02
	Jean/Sloan Heavy-haul Truck	1.35E-01	1.78E-04	4.22E-05	8.58E-03	3.48E-02	1.09E-01	1.07E-02	1.20E-01	1.79E-01	1.98E-01
	Nevada to Repository	4.04E-04	1.16E-06	4.16E-07	5.40E-05	2.19E-04	2.82E-04	7.75E-04	1.06E-03	6.78E-04	2.92E-03

Table 7-21. Potential LCFs from radiological exposure and pollution health effects and traffic fatalities in Nevada transportation, both incident-free and potential accidents, for the mostly truck scenario for the Proposed Action.

Regional Corridor	Public Incident-Free LCF	Worker Incident-Free LCF	Escort Incident-Free LCF	Accident LCF	Pollution Health Effects	Escort Pollution Health Effects	Traffic Deaths
Apex/Dry Lake Heavy-haul Truck	2.14E-03	2.84E-03	8.03E-04	1.00E-07	7.90E-04	1.23E-03	8.04E-03
Apex/Valley Modified Rail	6.00E-05	2.98E-03	3.04E-04	1.77E-10	1.91E-05	1.91E-05	1.22E-03
Beowawe/Carlin Rail	4.23E-04	3.64E-03	6.27E-04	2.10E-09	2.20E-04	2.20E-04	2.51E-03
Caliente Heavy-haul Truck	9.47E-04	3.15E-03	1.88E-03	1.53E-08	1.19E-04	1.86E-04	2.16E-02
Caliente Heavy-haul Truck Chalk Mountain	7.01E-04	2.97E-03	1.02E-03	4.05E-10	4.07E-06	5.79E-06	1.15E-02
Caliente Truck Las Vegas	3.23E-03	3.04E-03	1.34E-03	1.00E-07	7.75E-04	1.21E-03	1.53E-02
Caliente Rail	1.97E-05	3.29E-03	4.85E-04	1.42E-11	1.39E-06	1.39E-06	0.002
Caliente/Chalk Mountain Rail	1.25E-05	3.01E-03	3.43E-04	2.02E-12	1.41E-07	1.41E-07	0.001
Jean Rail	2.78E-03	3.14E-03	4.12E-04	1.31E-08	1.38E-03	1.38E-03	0.002
Jean/Sloan Truck	5.55E-03	2.98E-03	9.07E-04	2.22E-07	2.98E-03	3.90E-03	0.009
Truck Only Sites	0.170	0.745	0.000	2.61E-05	8.59E-02	0.00E+00	0.471

Table 7-22. Potential LCFs from radiological exposure and pollution health effects and traffic fatalities in National transportation, both incident-free and from potential accidents, for the mostly rail scenario for the Proposed Action.

Regional Corridor	Public Incident-Free LCF	Worker Incident-Free LCF	Escort Incident-Free LCF	Accident LCF	Pollution Health Effects	Escort Pollution Health Effects	Traffic Deaths
Apex/Dry Lake Truck	0.0744	0.192	0.149	2.76E-05	2.88E-02	3.53E-02	2.23E-01
Apex/Valley Modified Rail	0.0099	0.196	0.073	5.05E-07	4.66E-03	4.66E-03	3.82E-02
Beowawe/Carlin Rail	0.0158	0.220	0.157	7.74E-07	8.35E-03	8.35E-03	8.19E-02
Caliente Truck	0.0361	00.203	0.328	4.56 E-06	6.86E-03	7.86E-03	5.95E-01
Caliente Truck Chalk Mountain	0.0288	0.197	0.181	4.88 E-07	3.16E-03	3.19E-03	3.19E-01
Caliente Truck Las Vegas	0.108	0.199	0.236	2.76E-05	2.80E-02	3.45E-02	4.22E-01
Caliente Rail	0.0060	0.208	0.115	3.30E-07	2.78E-03	2.78E-03	6.12E-02
Caliente/Chalk Mountain Rail	0.0058	0.199	0.082	3.25E-07	2.74E-03	2.74E-03	4.39E-02
Jean Rail	0.0748	0.200	0.088	3.04E-06	3.76E-02	3.76E-02	4.56E-02
Jean/Sloan Truck	0.163	0.195	0.164	5.98E-05	8.93E-02	1.03E-01	2.36E-01
Truck Only Sites	0.0034	0.015	0.000	5.29E-07	1.59E-03	0.00E+00	9.81E-03

Table 7-23. The total number of transportation accidents for the Proposed Action.

Scenario	Regional Corridor	Inside Nevada Total	Outside Nevada Totals	Inside Plus Outside Nevada	Total Truck and Rail Accidents
Mostly Truck	Caliente Truck	0.061	0.062	0.123	66.58
Mostly Truck	Caliente Truck Chalk Mountain	0.033	0.062	0.095	66.55
Mostly Truck	Caliente Truck Las Vegas	0.043	0.062	0.105	66.56
Mostly Truck	Apex/Dry Lake Truck	0.022	0.062	0.084	66.54
Mostly Truck	Jean/Sloan Truck	0.024	0.062	0.086	66.54
Mostly Truck	Apex/Valley Modified Rail	0.003	0.062	0.065	66.52
Mostly Truck	Beowawe/Carlin Rail	0.006	0.037	0.043	66.50
Mostly Truck	Caliente Rail	0.004	0.062	0.066	66.52
Mostly Truck	Caliente/Chalk Mountain Rail	0.003	0.062	0.065	66.52
Mostly Truck	Jean Rail	0.003	0.062	0.065	66.52
Mostly Truck	Truck Only Sites	5.36	61.10	66.46	NA
Mostly Rail	Caliente Truck	1.97	7.70	9.68	11.44
Mostly Rail	Caliente Truck Chalk Mountain	1.05	7.70	8.76	10.52
Mostly Rail	Caliente Truck Las Vegas	1.40	7.70	9.10	10.86
Mostly Rail	Apex/Dry Lake Truck	0.72	7.69	8.41	10.18
Mostly Rail	Jean/Sloan Truck	0.76	7.68	8.44	10.20
Mostly Rail	Apex/Valley Modified Rail	0.09	7.67	7.76	9.53
	Beowawe/Carlin Rail	0.19	7.02	7.21	8.97
	Caliente Rail	0.14	7.71	7.85	9.61
	Caliente/Chalk Mountain Rail	0.10	7.71	7.81	9.57
	Jean Rail	0.10	7.68	7.78	9.55
	Truck Only Sites	0.11	1.65	1.76	NA

8.0 IMPACTS FROM MATERIAL AND COMMUTER TRANSPORTATION – BRANCH RAIL LINE AND HEAVY-HAUL ROUTE UPGRADE AND RESURFACE

8.1 Introduction

This section presents the following impacts from the construction and operation of a branch rail line or from heavy-haul route upgrade and resurfacing:

- Industrial safety impacts: TRCs, LWCs, and fatalities (Discussed in Section 5.2).
- Vehicle emission related fatalities from material movement and construction and operations commuting workers (factors discussed in Section 4.4)
- Traffic fatality impacts from material movement and construction and operations commuting

The calculation package contains this introduction and four groups of calculation files. Each group of files includes a table of contents. The files generally contain the following:

1. One file presents calculations of impacts of transporting materials for construction
2. One file presents calculations of impacts of transporting personnel for branch rail line construction and highway upgrading and maintenance

8.2 Methods

8.2.1 INDUSTRIAL SAFETY IMPACTS

Section 5.2 of this document presents the industrial safety impact factors for rail line construction and operation and heavy-haul route upgrade and operation, which were used along with the estimate of FTE workers to estimate industrial safety impacts.

8.2.2 TRAFFIC FATALITIES AND VEHICLE EMISSION IMPACTS

To estimate the traffic fatality and vehicle emissions impacts from the construction and operation of a branch rail line or the construction and operation of a heavy-haul route, the total kilometers traveled to deliver the materials of construction and the total commuting kilometers for workers who operate the operation of the branch rail line or maintain heavy-haul route and operate an intermodal transfer station and heavy-haul trucks were estimated. The total kilometers of travel were combined with the factors provided in Table 8-1 to determine the transportation impacts.

Table 8-1. Transportation Impact Factors

Fatality Rates	
1.00E-08 Fatalities per kilometer for all commuters (DIRS 148081-BTS 1999, all)	
1.67E-08 Fatality rate for large trucks (DIRS 103455-Saricks and Tompkins, 1999, Table 4)	
1.31E-09 Vehicle emission fatalities (per peson per square kilometer) – Autos – See Section 4.4	
2.09E-09 Vehicle emission fatalities (per person per square kilometer) – Trucks – See Section 4.4	
Round-trip distance (commuters and materials) miles	150
Round-trip distance (commuters and materials) kilometers	241

8.3 Assumptions

8.4 Use of Computer Software/Models

See Section 1.2 for a discussion of software used to estimate transportation impacts.

8.5 Calculation/Analysis And Results

The impacts from the construction and operation of a branch rail line or a heavy-haul route are provided on the transportation calculation package compact disk as Attachment 8A. Included in Attachment 8A is a table of contents that describes the files included on the attached Excel worksheets.

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10.0 ATTACHMENTS AND APPENDIXES

Note: **Appendices are appended to the document, in print.**

Appendix A: Final Yucca Mountain Environmental Impact Statement Transportation Database User's Guide (Contains its own Appendices A, B, C, & D)

Appendix B: Excel Files for Severe Accident Release Fraction Modeling by Fuel Type

Appendix C: Modification of DIRS 152476 (Sprung, et al, 2000) Release Model for Different Fuel Types

Appendix D: Canister Failure Rates

Appendix E: Stress Calculation for DOE Spent Fuel Canister Heated to 1,000°C (1,273°K)

Appendix F: Development Of Nevada County Vehicle Densities

Appendix G: Estimates of Materials Transported to the Repository, Workers Traveling to the Repository, and Site Generated Waste Transported From the Repository

Appendix H: Impacts of Using 2000 Census Population Data

Appendix I: Development Plan

Note: **Attachments are appended to the document electronically on a read-only compact disk that accompanies the document; Table references are to tables in the calculation package.**

Attachment Name	Attachment Description
Transportation Database	ACCESS 2000 relational database for calculating impacts
Database User Guide	Word document; user guide for the Transportation Database
Attachment 1A	Word document; Transportation Database verification documentation
Attachment 2A	Excel spreadsheet; SNF shipment data (Table 2-14)
Attachment 31A	Route distance and population density data; HIGHWAY and INTERLINE input and output text files (Tables 3-7, 3-11, 3-12)
Attachment 32A	HIGHWAY and INTERLINE source code ; text file
Attachment 33A	Nevada routing and population data including maps generated by Arcview/ArcInfo (Table 3-31)
Attachment 34A	Nevada demographic and REMI projections; text file (Table 3-34)
Attachment 41A	Word document; average isotope inventories (Table 4-3)
Attachment 42A	RADTRAN 5 incident-free input and output files; text files (Table 4-22). Excel spreadsheet; offline calculations and compilation of RADTRAN incident free unit risk factors (Table 4-22).
Attachment 532A	Excel spreadsheets; release fraction calculations for DOE fuels and HLW (Table 5-15)
Attachment 532B	Excel spreadsheet; ingestion dose calculation from ground deposition. RADTRAN 5 input and output text files for other accident per-curie doses for each isotope; RADTRAN input and output text files for loss of shielding (Table 5-54)
Attachment 53A	RISKIND input and output text files for the maximum foreseeable accident (Table 5-62)
Attachment 54A	RISKIND input and output text files sabotage and terrorism vents (Table 5-71)
Attachment 63A	Excel spreadsheet; calculation of impacts of transporting materials, workers, and site-generated waste
Attachment 8A	Excel spreadsheet; calculation of impacts of rail line construction
Attachment H5A	WebTRAGIS input and output files for Appendix H. Access Database for calculating impacts presented in Appendix H.

Appendices

Appendix A:	**Final Yucca Mountain Environmental Impact Statement Transportation Database User's Guide**
Appendix B:	**Excel Files for Severe Accident Release Fraction Modeling by Fuel Type**
Appendix C:	**Modification of DIRS 152476 (Sprung, et al. 2000) Release Model for Different Fuel Types**
Appendix D:	**Canister Failure Rates**
Appendix E:	**Stress Calculation for DOE Spent Fuel Canister Heated to 1,000ºC (1,273ºK)**
Appendix F:	**Development Of Nevada County Vehicle Densities**
Appendix G:	**Estimates of Materials Transported to the Repository, Workers Traveling to the Repository, and Site Generated Waste Transported From the Repository**
Appendix H:	**Impacts of Using 2000 Census Population Data**

Appendix A

Final Yucca Mountain Environmental Impact Statement Transportation Database User's Guide

Final

Yucca Mountain

Environmental Impact Statement

Transportation Database

User's Guide

U.S. Department of Energy
Office of Civilian Radioactive Waste Management

August 2001

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GLOSSARY

The terms in this glossary are defined in order to clarify their specific use in the database fields. The glossary includes both terms used in the EIS (and defined in the EIS glossary) and terms that are unique to this Transportation Database User Guide. A note is provided in the definition in cases where a particular term is used differently in the EIS and in the Transportation Database User Guide.

accident
An unplanned sequence of events that results in undesirable consequences. In the Transportation Database User's Guide, accident specifically refers to vehicular accidents during the transportation of radioactive materials. A vehicular accident is defined by the U. S. Department of Transportation as a vehicular incident that results in a death, an injury, or damage to the vehicle such that it cannot move under its own power.

barge transportation
Transportation of loaded and empty rail casks between a commercial facility and a nearby railhead using navigable waterways. Barge terminals would have intermodal transfer capabilities sufficient to transfer casks from barges to railcars.

case
Option for transporting nuclear waste in which the use of a particular mode of transportation is maximized. Cases in the database include the Mostly Truck Case, the Mostly Rail Case, and the Barge Case. In the EIS, cases are called "scenarios"; the term "case" describes a particular combination of accident severity and release or loss-of-shielding fraction.

cask
A heavily shielded container that meets the applicable regulatory requirements used to ship spent nuclear fuel or high-level radioactive waste. The Transportation Database User's Guide uses only the transportation-related definition of "cask."

classification stop
A 30-hour rail stop at the origin or terminus of a trip. Cars are loaded and reclassified into trains at classification stops.

cloudshine (immersion) dose risk
Dose risk as a result of being immersed in air containing dispersed radioactive material. See also "dose risk."

commercial spent nuclear fuel
Commercial nuclear fuel rods that have been removed from reactor use.

corridor
As used in the transportation analysis in this EIS, a strip of land, approximately 400 meters (0.25 mile) wide, that encompasses one of several possible routes through which DOE could build a branch rail line to transport spent nuclear fuel, high-level radioactive waste, and other material to and from the proposed Yucca Mountain Repository.

crew
Truck and railyard crewmembers.

disposal
The emplacement in a repository of high-level radioactive waste, spent nuclear fuel, or other highly radioactive material, and the isolation of such waste from the accessible environment.

DOE spent nuclear fuel
Radioactive waste created by defense activities that consists of over 250 different types of spent nuclear fuel and is expected to contribute 2,333 metric tons of heavy metal to the total repository. Includes 65 metric tons of heavy metal of naval spent nuclear fuel.

dose
The amount of radioactive energy taken into living tissues. In the Yucca Mountain EIS Transportation Database User's Guide, dose is expressed in units of rem: the ratio of biological damage to energy absorbed and a function of radiation taken in, the body weight or mass impacted, and the time over which the dose occurs or the impact (that is, the positive or negative effect of an action on the natural environment) is measured.

dose conversion factor
Radionuclide and pathway-specific factor used to convert radionuclide uptake in curies to population dose in person-rems.

dose risk
The product of a radiation dose and the probability of its occurrence. In the Yucca Mountain EIS Transportation Database User's Guide, the potential radiation dose from a vehicular accident is called a "dose risk" because the calculation includes the probability of accident occurrence and the conditional probability of an accident of a particular severity.

end node
Termination point for a mode of transport for nuclear waste. These include the intermodal transfer points in the origin state, the six rail end nodes in Nevada, and the repository itself for legal-weight truck.

escort
Individuals required by regulation, for highway and rail shipments. Transporting spent nuclear fuel to the Yucca Mountain site would require the use of physical security and other escorts for the shipments. For truck shipments in highly populated (urban) areas, regulations require two escorts, one of which must be in a vehicle that is separated from the shipment vehicle. For rail shipments in urban areas, at least two escorts must maintain visual surveillance of a shipment from a railcar that accompanies a cask car. For truck shipments in areas that are not highly populated (suburban and rural), regulations require one escort; this individual may ride in the cab of the shipment vehicle. For rail shipments in areas that are not highly populated (suburban and rural), at least one escort must maintain visual surveillance of the shipment from a railcar that accompanies a cask car.

food transfer factor
Radionuclide-specific and state-specific factor used to convert radionuclide ground contamination to population dose via the food pathway.

groundshine dose risk
The dose risk to an individual as a result of radioactive material deposited on the ground. See also "dose risk."

heavy-haul truck
An overweight, overdimension vehicle that must have permits from state highway authorities to use public highways; a vehicle DOE would use on public highways to move spent nuclear fuel or high-level radioactive waste shipping casks designed for a railcar.

incident-free transportation
Routine transportation in which cargo travels from origin to destination without being involved in an accident.

incident-free dose
Incident-free radiological impacts occur from exposure, during normal transportation, to external radiation in the vicinity of the transportation casks. The term sometimes includes health impacts of transportation vehicle emissions and fugitive dust.

ingestion dose risk
The dose risk to an individual as a result of ingestion of contaminated crops or foods produced on contaminated lands. See also "dose risk."

inhalation dose risk
The dose risk to an individual as a result of inhaling air containing dispersed radioactive material. See also "dose risk."

inspection dose
The dose to an individual during cask and/or vehicle inspection.

intermodal
The use of multiple modes of transportation for carrying waste.

intermodal transfer station
A facility at a juncture of rail and road transportation used to transfer shipping casks containing spent nuclear fuel and high-level radioactive waste from rail to truck, and empty casks from truck to rail.

legal-weight truck
A truck with a gross vehicle weight (both truck and cargo weight) of less than 80,000 pounds, which is the loaded weight limit for commercial vehicles operated on public highways without special state-issued permits. In addition, the dimensions, axle spacing, and, if applicable, axle loads of these vehicles must be within Federal and state regulations.

naval spent nuclear fuel
Spent nuclear fuel discharged from reactors in surface ships, submarines, and training reactors operated by the U.S. Navy.

non-radioactive pollution health effects
Health effects attributed to the release of truck and train exhaust emissions and fugitive dust.

non-radioactive traffic fatalities
Vehicle-related fatalities resulting from traffic accidents during the transportation of radioactive materials.

nuclear waste
Unusable by-products of nuclear power generation, nuclear weapons production, medical and industrial applications, and research, including spent nuclear fuel and high-level radioactive waste.

offlink population
Persons who live along the route of travel used for the transportation of radioactive material, including pedestrians in urban areas.

onlink population
Persons in vehicles that would share transportation routes with radioactive materials shipments.

overnight stop dose
The dose to an individual as the result of an overnight stop by a heavy-haul truck carrying waste.

origin
Site from which nuclear waste would be shipped, which consists of one or more pools. Distances to the Yucca Mountain Repository are determined using the origin as a starting point.

person-rem
A unit used to measure the radiation exposure to an entire group of people and to compare the effects of different amounts of radiation on groups of people; it is the product of the average dose equivalent (in rem) to a given organ or tissue multiplied by the number of persons in the population of interest.

physical/chemical groups
Categories of materials that behave similarly in an accident environment. The five physical/chemical groups in the database are inert (noble) gases, volatile substances (cesium, iodine, etc.), ruthenium, particulate matter, and crud.

pool
Water-filled basin for storing commercial spent nuclear fuel. The number of shipments is determined from the volume of commercial spent nuclear fuel at each pool and the type of cask used to ship the commercial spent nuclear fuel. In order to maintain consistency in the database, all nuclear waste storage sites are identified as having pools, even if the nuclear waste is not stored in a water filled-basin.

rail transportation
Includes railroad transportation of spent nuclear fuel and high-level radioactive waste in large rail transportation casks (rail casks). The casks would be placed on railroad cars at commercial and Department of Energy sites or at nearby intermodal transfer facilities for shipment on trains operated by commercial railroad companies over existing tracks. Because of the weight of the casks, only one cask would be transported on a railcar.

release fractions
Fraction of each isotope in spent nuclear fuel or high-level radioactive waste that could be released during an accident. In the Yucca Mountain Transportation Database User Guide, release fractions differ for different physical/chemical groups of materials.

resuspension dose risk
The dose risk to an individual as a result of inhalation of radioactive particles resuspended by wind from the ground. See also "dose risk."

risk
The product of the probability that an undesirable event will occur and the consequences of the event.

spent nuclear fuel
Fuel that has been withdrawn from a nuclear reactor following irradiation, the component elements of which have not been separated by reprocessing. For this project, this refers to (1) intact, nondefective fuel assemblies; (2) failed fuel assemblies in canisters; (3) fuel assemblies in canisters; (4) consolidated fuel rods in canisters; (5) nonfuel assembly hardware inserted in pressurized-water reactor fuel assemblies; (6) fuel channels attached to boiling-water reactor fuel assemblies; and (7) nonfuel assembly hardware and structural parts of assemblies resulting from the consolidation of canisters.

stop dose
Refers to the collective doses for individuals who could be exposed while a shipment was stopped en route. For truck transportation, these would include stops for refueling, food, rest, and in-transit inspections. For rail transportation, stops would occur in railyards along the route to switch railcars from inbound trains to outbound trains traveling toward the Yucca Mountain site, and to change train crews and equipment (locomotives).

unit risk factor

A dose or dose risk for which one or more of the parameters is unity. For example, the off-link incident-free unit risk factor is the dose during transport of one shipment of nuclear waste traveling one kilometer through populated areas with a population density of one person per square kilometer. This unit risk factor would then be multiplied in the database by the number of shipments and the distance traveled and the population density for each route segment.

For accident analysis, a unit risk factor can be the dose risk from an accident occurring on one kilometer and potentially releasing one curie of a radionuclide (release fraction = 1) with potential impacts of a population density of one person per square kilometer. The unit risk factor would then be multiplied by the curie inventory for the particular radionuclide, the per-kilometer accident probability, the product of conditional severity probabilities and release fractions, and the length and population density of the route segment.

1. INTRODUCTION

The Yucca Mountain Environmental Impact Statement (EIS) Transportation Database is used to compile the results for the *Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada.* The database uses results from the CALVIN (DIRS 134391-CRWMS M&O 1998, all), RADTRAN (DIRS 155430-Neuhauser et al. 2000, all), RISKIND (DIRS 101483-Yuan et al. 1995, all), INTERLINE (DIRS 104781-Johnson et al. 1993a, all), and HIGHWAY (DIRS 104780-Johnson et al. 1993b, all) computer codes to compile transportation-related impacts of transporting spent nuclear fuel and high-level radioactive waste from commercial reactors and U.S. Department of Energy (DOE) facilities to Yucca Mountain. For accident scenarios, the database uses data from these computer codes to calculate dose risks for the ingestion, inhalation, resuspension, immersion (cloudshine), and groundshine pathways as well as non-radioactive traffic fatalities. For the incident-free transportation scenario, the database uses data from these computer codes to calculate doses to offlink populations, onlink populations, people at stops, crews, inspectors, workers at intermodal transfer stations, guards at overnight stops, and escorts, as well as non-radioactive pollution health effects. Exposures to offlink populations, onlink populations, and to individuals during stops are summed to provide estimates of public dose.

The Yucca Mountain EIS Transportation Database was developed using Microsoft Access 2000 software and the Microsoft Windows 2000 operating system. The database consists of tables for storing data, forms for selecting data for querying, and queries for retrieving the data in a predefined format. This user's guide provides a description of the forms, tables, and queries that have been developed in the database to perform the accident risk and incident-free dose calculations. Appendix A provides descriptions of the queries used in the database. Appendix B provides descriptions of the calculations performed by database queries. Appendix C describes the special functions that are used to find and return data. Appendix D describes how the RADTRAN code was used in conjunction with the database.

The database provides results at many levels of summation (for example, national, state, Nevada county, origin, segment, and mode). The database provides results for four transportation modes—legal-weight truck, heavy-haul truck, rail, and barge—which are the combined to create the Mostly Truck Case, the Mostly Rail Case, and the Barge Case.

For the rail mode in the Mostly Rail and Barge Cases, the database provides results for 10 transportation implementing alternatives in Nevada. For the Nevada implementing alternatives, the database compiles the transportation risks for rail shipments to rail end nodes in Nevada and subsequent rail or heavy-haul truck shipments from the rail end nodes to the repository. The rail end nodes are Apex, Beowawe, Caliente, Dry Lake, Eccles, and Jean.

In the Mostly Truck Case, the database provides results for legal-weight truck shipments and a small number of rail shipments to the repository. In the Mostly Rail Case, the database provides results for rail, heavy-haul truck, and legal-weight truck shipments to the repository. The Barge Case is very similar to the Mostly Rail Case. In the Barge Case, barge transport is substituted for heavy-haul truck transport to nearby railheads for 17 sites without direct rail access.

The closest railheads for heavy-haul truck and the closest docks for barge are referred to as "Transfer" end nodes in the database. This label distinguishes these intermodal transfer points from the rail end nodes in Nevada.

2. DATABASE FORMS

Forms have been developed in the database to aid the user in selecting (1) a query to run, (2) the parameters for the query, and (3) the data entry of shipments, cases, and shipment kilometers. When the database opens, the Select Query form is displayed (Figure 1). This form provides many different parameter options for viewing the data in distinct subsets; for example, accident dose risks can be viewed for one mode through one state for one fuel type. The user can select a query, select individual values for a parameter or all values for a parameter, execute the query, and the results for the selected query and parameter values will be returned from the database.

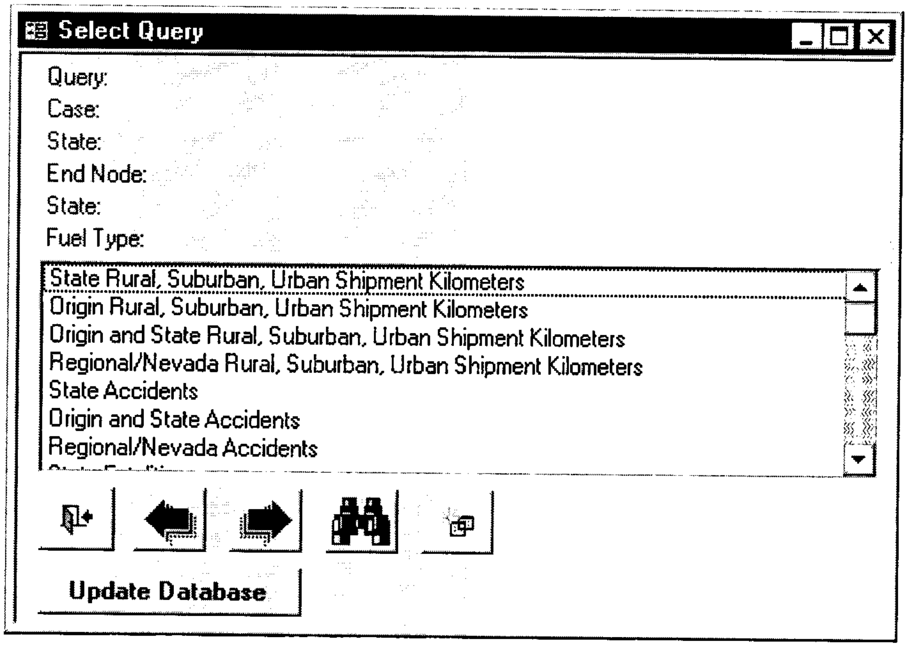
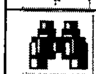


Figure 1. Select Query Form

Table 1 provides brief descriptions of the functions of the buttons on the form.

Table 1. Button Descriptions

Button	Description
	Close Form button
	Previous button: Reselect previous parameter
	Next button: Select next parameter
	View Results button: Run the selected query using selected parameters
	Start Over button: Reselect query to run
	Update Database button: Update data stored in calculated values tables. In the read-only versions of the database, the Update Database button is not present.

The first step is to select a query to run. The queries are generally in order from least to most complex (for example, shipment kilometers to accident dose risks). Once a query is selected, the user can press the Next button to see the selection of parameter values. Most of the parameter values (for example, Mode, End Node, States) allow the selection of "All" as the first value in the list.

If a required parameter value is not selected, a message will appear informing the user that a selection is required.

After all required parameter values have been selected, the user can press the View Results button or the Next button again to display the query results for the selected parameter values.

To run a different query or to clear all of the selected parameter values, press the Start Over button and a new query can be selected.

The following is an example query to view the shipment kilometers by origin, state, and population zone outside Nevada. The user would first select the Origin and State Rural, Suburban, and Urban Shipment Kilometers outside NV query (Figure 2).

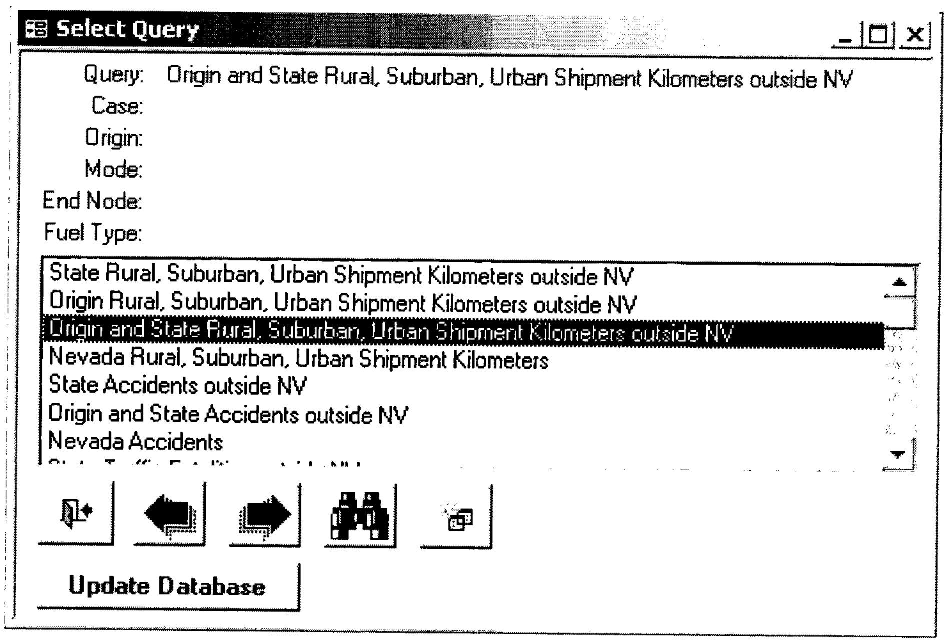


Figure 2. Select Query

The user would press the Next button to select the case (Figure 3). The user can select a single case or all cases.

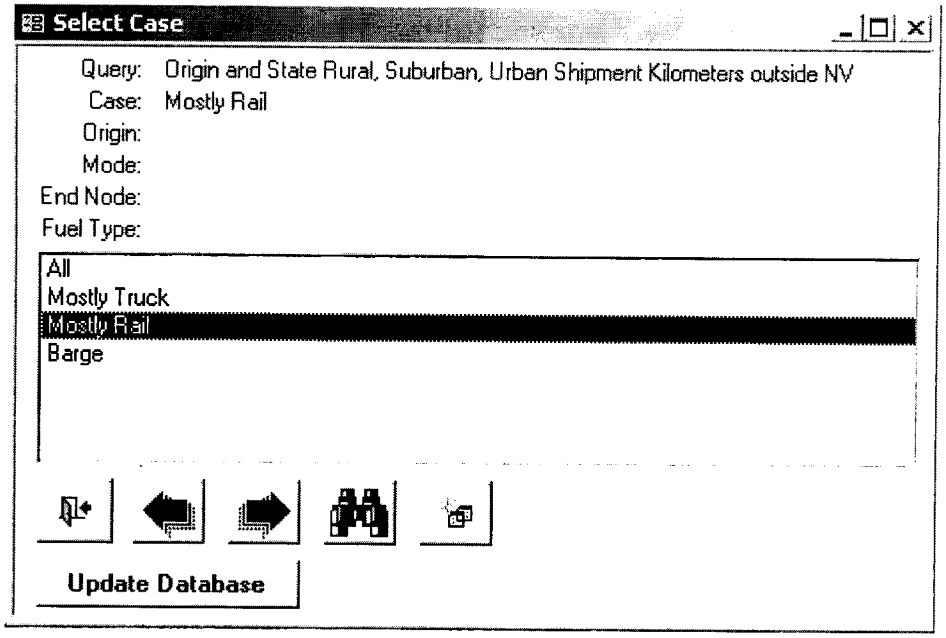


Figure 3. Select Case

The user would press the Next button and select the origin (Figure 4). The user can select a single origin or all origins.

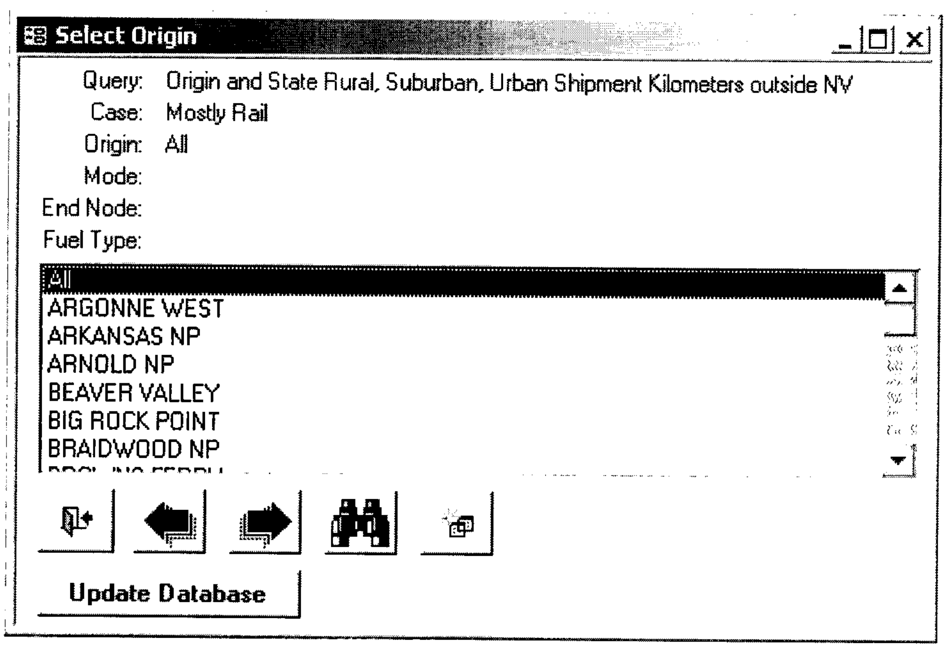


Figure 4. Select Origin

The user would press the Next button and select the mode (Figure 5). The user can select a single mode or all modes.

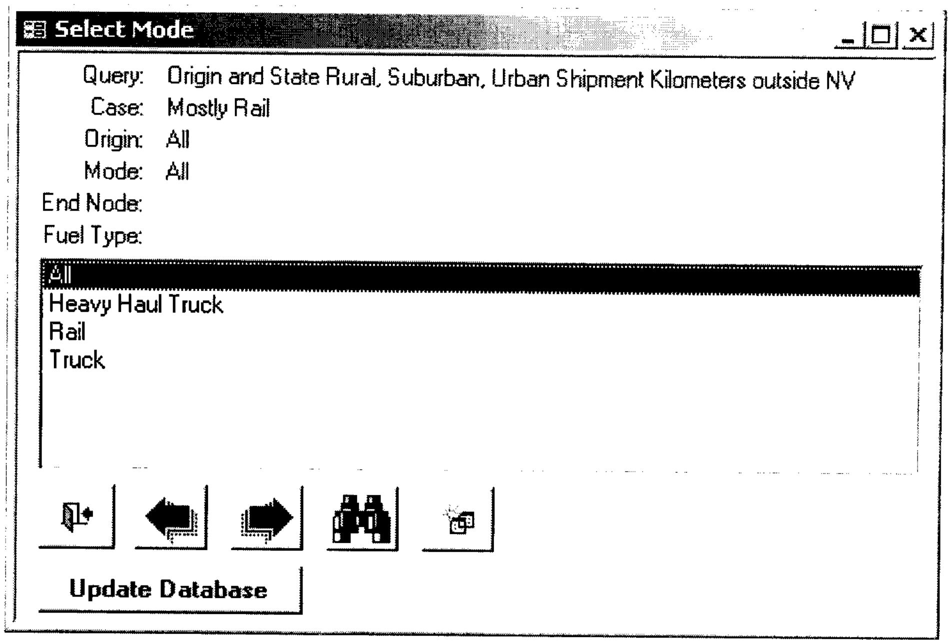


Figure 5. Select Mode

The user would press the Next button and select the end node (Figure 6). The user can select a single end node or all end nodes.

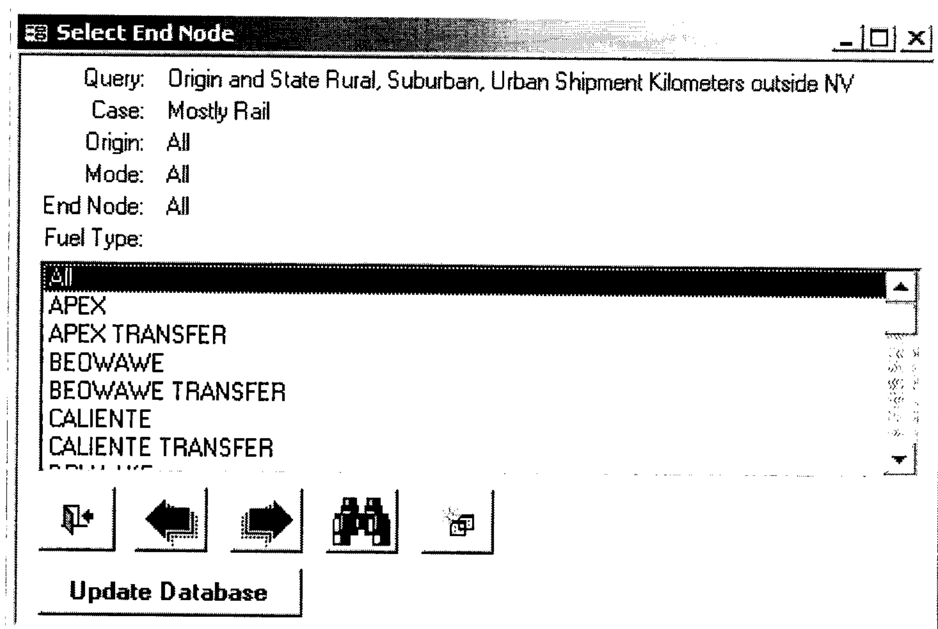


Figure 6. Select End Node

The user would press the Next button and select the fuel type (Figure 7). The user can select a single fuel type or all fuel types.

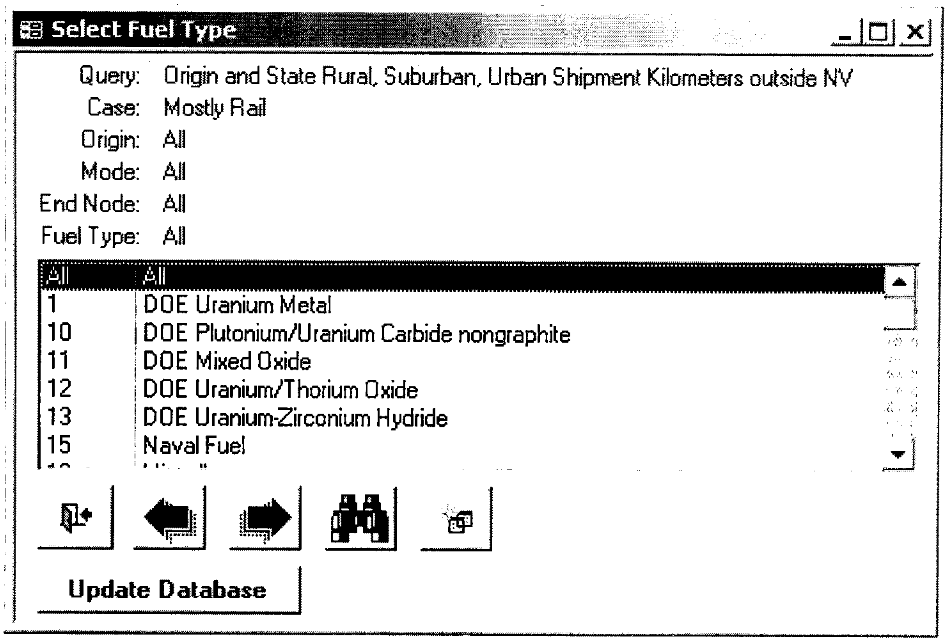
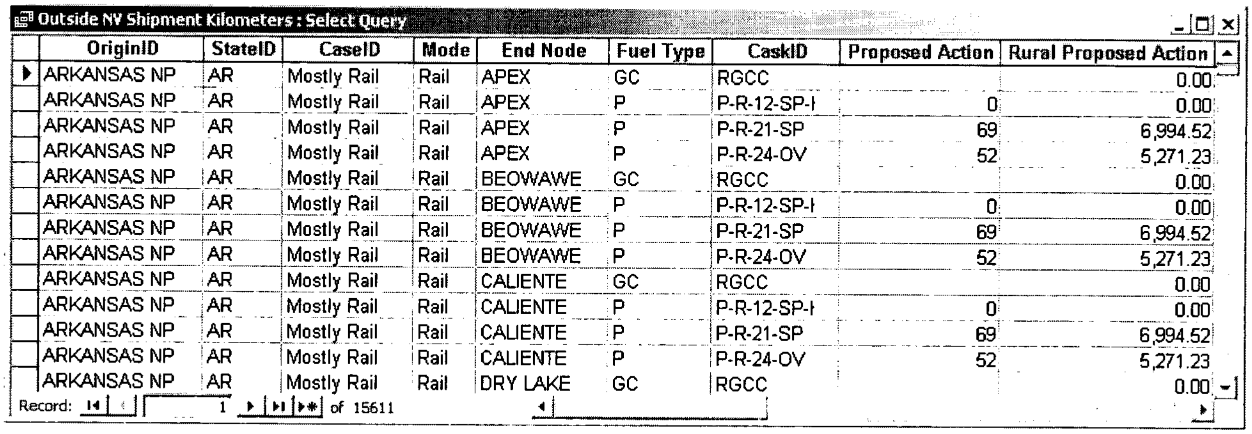


Figure 7. Select Fuel Type

The user would press the View Results button , and the Outside NV Shipment Kilometers query will be executed with the selected parameter values. The results for the Outside NV Shipment Kilometers query would be displayed, as shown in Figure 8.

Many of the queries in the database are based on the calculated values tables. These tables were developed because data in the database are not expected to change frequently. However, if information in one of the tables is updated, the data in the calculated values tables must be updated as well. To update calculated values tables, press the Update Database button **Update Database**. The time required to complete the update may be several hours (12 to 24) and is dependent on the computer processor being used. In the read-only versions of the database, the Update Database button is not present.



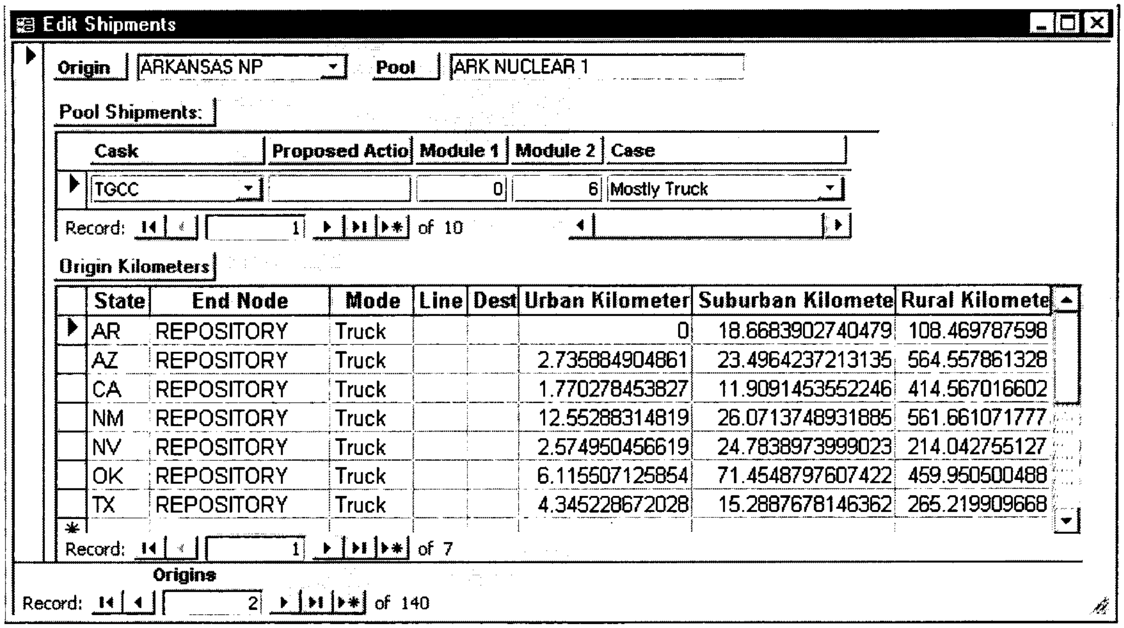
Outside NV Shipment Kilometers : Select Query

OriginID	StateID	CaseID	Mode	End Node	Fuel Type	CaskID	Proposed Action	Rural Proposed Action
ARKANSAS NP	AR	Mostly Rail	Rail	APEX	GC	RGCC		0.00
ARKANSAS NP	AR	Mostly Rail	Rail	APEX	P	P-R-12-SP-I	0	0.00
ARKANSAS NP	AR	Mostly Rail	Rail	APEX	P	P-R-21-SP	69	6,994.52
ARKANSAS NP	AR	Mostly Rail	Rail	APEX	P	P-R-24-OV	52	5,271.23
ARKANSAS NP	AR	Mostly Rail	Rail	BEOWAWE	GC	RGCC		0.00
ARKANSAS NP	AR	Mostly Rail	Rail	BEOWAWE	P	P-R-12-SP-I	0	0.00
ARKANSAS NP	AR	Mostly Rail	Rail	BEOWAWE	P	P-R-21-SP	69	6,994.52
ARKANSAS NP	AR	Mostly Rail	Rail	BEOWAWE	P	P-R-24-OV	52	5,271.23
ARKANSAS NP	AR	Mostly Rail	Rail	CALIENTE	GC	RGCC		0.00
ARKANSAS NP	AR	Mostly Rail	Rail	CALIENTE	P	P-R-12-SP-I	0	0.00
ARKANSAS NP	AR	Mostly Rail	Rail	CALIENTE	P	P-R-21-SP	69	6,994.52
ARKANSAS NP	AR	Mostly Rail	Rail	CALIENTE	P	P-R-24-OV	52	5,271.23
ARKANSAS NP	AR	Mostly Rail	Rail	DRY LAKE	GC	RGCC		0.00

Record: 1 of 15611

Figure 8. Example of Query Results

The database includes an Edit Shipments form (Figure 9), which allows the input and update of waste shipments; cases the shipments apply to; and urban, suburban, and rural shipment kilometers through states. Newly added or updated records are saved to the database when all required information has been entered correctly and the user either moves off the record or closes the form.



Edit Shipments

Origin ARKANSAS NP Pool ARK NUCLEAR 1

Pool Shipments:

Cask	Proposed Actio	Module 1	Module 2	Case
TGCC		0	6	Mostly Truck

Record: 1 of 10

Origin Kilometers

State	End Node	Mode	Line	Dest	Urban Kilometer	Suburban Kilomete	Rural Kilomete
AR	REPOSITORY	Truck			0	18.6683902740479	108.469787598
AZ	REPOSITORY	Truck			2.735884904861	23.4964237213135	564.557861328
CA	REPOSITORY	Truck			1.770278453827	11.9091453552246	414.567016602
NM	REPOSITORY	Truck			12.55288314819	26.0713748931885	561.661071777
NV	REPOSITORY	Truck			2.574950456619	24.7838973999023	214.042755127
OK	REPOSITORY	Truck			6.115507125854	71.4548797607422	459.950500488
TX	REPOSITORY	Truck			4.345228672028	15.2887678146362	265.219909668

Record: 1 of 7

Origins

Record: 2 of 140

Figure 9. Edit Shipments

3. DATABASE TABLES

The Yucca Mountain EIS Transportation Database was designed and developed using analysis and modeling of data that were collected and developed for the transportation portion of the Yucca Mountain EIS. Standard relational database design was used to create and develop the database tables and relationships between tables. This section describes the structure of the tables, the sources for the data stored in the tables, the procedures for entering data into the tables, and the relationships between tables.

3.1 Tables

Tables are used to store data in the database and are defined as lookup (typically, small standardized sets of data), join (data from lookup tables joined together where appropriate), or calculated values tables. The tables are normalized so only the data related to the primary key or primary use of the table are stored in the table. Due to the processing time required to calculate some database values and the static nature of the data stored in the database, calculated values such as shipment kilometers and accident doses have been stored in tables of calculated values. Table 2 lists the names of the tables in the database, the table type (lookup, join, or calculated values), and the sources for all data sets stored in the table.

Table 2. Yucca Mountain EIS Transportation Database Tables and Sources (1 of 2)

Table Name	Table Type	Contents	Source(s)
Origins	Lookup	Origin Name, Origin State	Section 3.0, Transportation Calculation Package
Pools	Lookup	Pool Name, Origin, CALVIN Pool Name	Section 2.0, Transportation Calculation Package
Casks	Lookup	Cask Name, Fuel Type, Number of Assemblies	Section 2.0, Transportation Calculation Package
States	Lookup	State Name, Population Escalation Factor	Section 3.0, Transportation Calculation Package
Cases	Lookup	Case Name	Project input
End Nodes	Lookup	End Node Name, End Node Nevada County, End Node Nevada County Population Density	Section 3.0, Transportation Calculation Package
Modes	Lookup	Mode Name	Project input
Fuel Types	Lookup	Fuel Type Name, Fuel Type Description, Transportation Index	Sections 2.0 and 4.0, Transportation Calculation Package
Isotopes	Lookup	Isotope Name, Group, Accident Unit Risk Factors	Section 5.0, Transportation Calculation Package
Groups	Lookup	Group Name, Respirable Fraction, Dispersion Factor	Section 5.0, Transportation Calculation Package
Unit Risk Factors	Lookup	Mode Name, Incident Free Unit Risk Factors, Escort Fatality Unit Risk Factor	Section 4.0, Transportation Calculation Package
Kilometers	Join	Distances and Population Densities by state and mode for an Origin to End Node	Section 3.0, Transportation Calculation Package

Table 2. Yucca Mountain EIS Transportation Database Tables and Sources (2 of 2)

Table Name	Table Type	Contents	Source(s)
Regional Corridors	Join	Distances and Population Densities by NV County and mode for Regional Alternatives	Project Input
Shipments	Join	Proposed Action, Module 1, and Module 2 shipments by Pool and Cask	Section 2.0, Transportation Calculation Package
Casks/Modes	Join	Cask Name, Mode, Accident Severity Probabilities, Loss of Shielding Severity Probabilities and Exposure Factors	Created from distinct values obtained by combining shipments (casks) and routing (modes)
Cases/Kilometers	Join	Case Name, Kilometer ID	Created based on routing information
Cases/Shipments	Join	Case Name, Shipment ID	Created based on shipment information
Accident Rates	Join	Urban and Rural Accident and Fatality Rates by State and Mode	Section 5.0, Transportation Calculation Package
Food Transfer Factors	Join	Food Transfer Factors by State and Isotope	Section 5.0, Transportation Calculation Package
Curies per Assembly	Join	Curies per Assembly by Isotope and Fuel Type	Attachment 41A, Transportation Calculation Package
Release Fractions	Join	Release Fraction Severities by Group, Fuel Type, and Mode	Section 5.0, Transportation Calculation Package
Nevada Traffic Counts	Join	Nevada Traffic Counts by Mode and County	Section 4.0, Transportation Calculation Package
OutsideNevadaShipmentKilometers	Calculated Values	Shipment Kilometers outside NV by Population Zone for an Origin, State, Case, Mode, End Node, Fuel Type, and Cask	Created by a query
NevadaShipmentKilometers	Calculated Values	Shipment Kilometers in NV by Population Zone for an Origin, State, Case, Mode, End Node, Fuel Type, and Cask	Created by a query
OutsideNevadaAccidentDose	Calculated Values	Accident Dose Risk outside NV by Origin, State, Case, Mode, End Node, and Fuel Type	Created by a query
NevadaAccidentDose	Calculated Values	Accident Dose Risk in NV by Origin, State, Corridor, Case, Mode, End Node, and Fuel Type	Created by a query
NevadaEISIncidentFreeDose	Calculated Values	Incident Free Dose Risk in NV by Case and Corridor	Created by a query
NevadaEISAccidentDose	Calculated Values	Accident Dose Risk in NV by Case and Corridor	Created by a query
NationalEISIncidentFreeDose	Calculated Values	National Incident Free Dose Risk by Case and Corridor	Created by a query
NationalEISAccidentDose	Calculated Values	National Accident Dose Risk by Case and Corridor	Created by a query

Data in lookup tables are related to data in join tables where appropriate. For example, records from the States, Origins, End Nodes, and Modes tables are linked to the Kilometers table to determine the distances a shipment will travel in a state from an origin to an end node by a mode.

3.2 Data Input

Data are input into the database using the following five steps:

- Electronically copying spreadsheet source information to temporary tables
- Formatting the temporary tables to match the structure of the existing normalized tables
- Deleting previously input data
- Appending data from the temporary table to the existing table
- Appending data to any other table that is dependent on that table

For example, when new routing is provided to the database, the data are formatted to match the structure of the Kilometers table. After existing routing records are deleted from the Kilometers table and the new routing records are appended to the Kilometers table, records must be appended to the Cases/Kilometers table to allow the modeling of the cases (that is, the Mostly Truck, Mostly Rail, or Barge Cases) in which the new routing records are used. In the read-only versions of the database, input data cannot be changed.

3.3 Table Relationships

Table relationships within the database are designed to provide referential integrity and data consistency. For example, when a record is deleted from a lookup table, all of the related records in a join table are also deleted; this provides referential integrity. The requirement that a record exists in a lookup table before it can be used as part of a record in a join table provides data consistency by controlling what information can be entered in the join table. Figure 10 shows the relationships between the tables in the Yucca Mountain EIS Transportation Database.

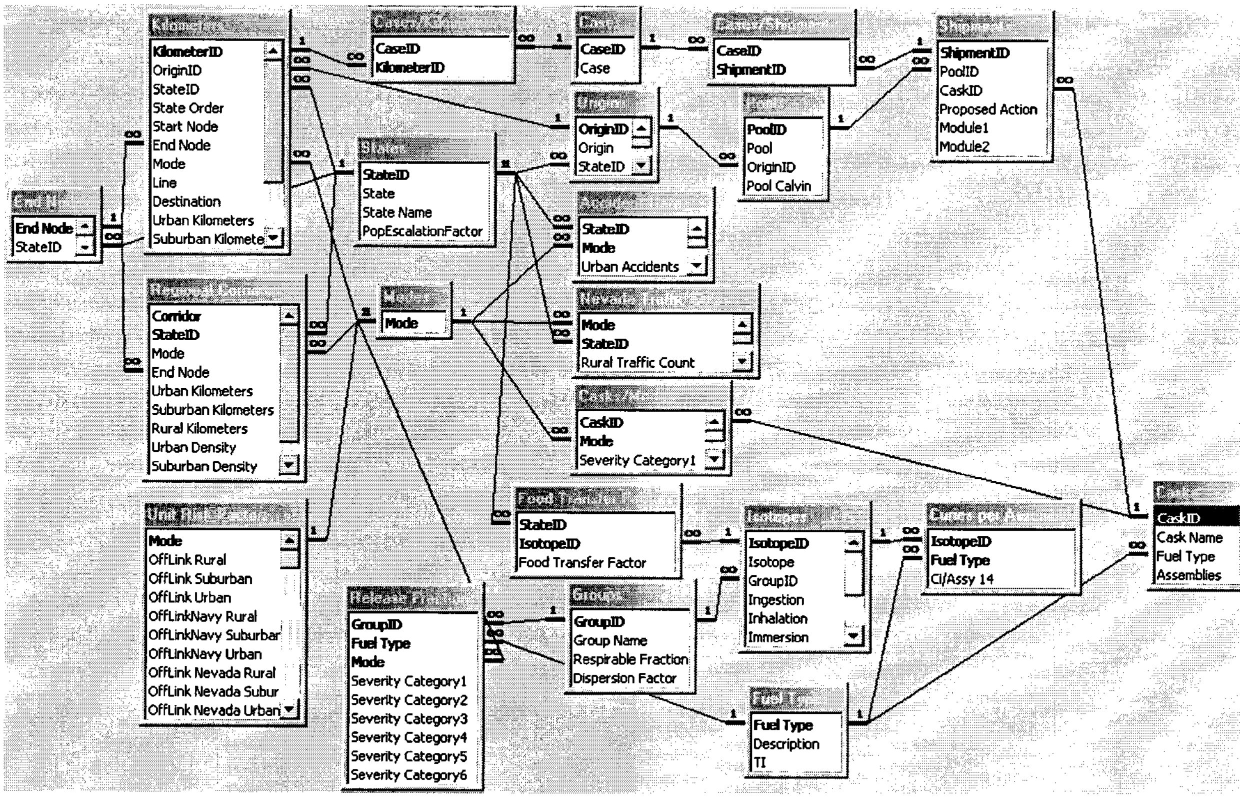


Figure 10. Relationships of Tables in Yucca Mountain EIS Transportation Database

The lines between the tables define relationships. The lines can indicate either a one-to-one relationship or a one-to-many relationship. The infinity symbol represents "many" in the one-to-many relationship. Typically, "one" in a one-to-many relationship is defined as coming from a lookup table, and "many" is defined as going to a join table. For example, the Modes table contains the distinct list of modes (entered once) that can be used in many records in the Accident Rates table.

The relationships also maintain consistency in the process of updating and deleting of records. For example, the values Barge, Heavy Haul Truck, Rail, and Truck in the Modes table can only be used in the Mode field of tables related to the Mode field of the Modes table. These tables include Kilometers, Regional Corridors, Accident Rates, Casks/Modes, Release Fractions, Nevada Traffic Counts, and Unit Risk Factors. Referential integrity ensures that changes to values in the Modes tables are automatically updated in the related tables. Also, if one of the values in the Modes table is deleted, the records in the related tables with that value in the Mode field will be automatically deleted as well. In the read-only versions of the database, records cannot be deleted.

4. DATABASE QUERIES

Queries were created in the database to calculate the accident risks and incident-free dose risks, as well as the many intermediate calculations required to calculate dose risks. The queries use input from the tables and other queries to perform the accident risk and incident-free dose risk calculations. Appendix A provides a description and the input sources for the queries. In the read-only versions of the database, the input data tables cannot be changed and all the queries related to updating of database tables have been disabled.

4.1 Query Calculations

Appendix B provides the queries and equations used to calculate ingestion, inhalation, resuspension, immersion (cloudshine), and groundshine dose risks as well as non-radioactive traffic fatalities for the accident scenario. Appendix B also provides the queries and equations used to calculate dose consequences for the offlink populations, onlink populations, stops, crews, inspections, intermodal, and escorts, as well as the non-radioactive pollution health effects for the incident-free transportation scenario. The public dose for commercial spent nuclear fuel, DOE spent nuclear fuel, and high-level waste is the sum of the offlink population exposure, onlink population exposure, and exposures during stops. The total public dose is the sum of the doses from transportation of commercial spent nuclear fuel, DOE spent nuclear fuel, naval spent nuclear fuel, and high-level radioactive waste.

4.2 Query Hierarchies

Queries were developed in a hierarchical manner, where the results of one query are used as input to a higher-level query. In most cases, when a query at a higher level in the hierarchy is executed, all of the associated lower level queries are also executed. To provide flexibility in the data output, queries were developed in six categories: Outside NV Incident Free, Outside NV Accident, Nevada Incident Free, Nevada Accident, Incident Free Combined, and Accident Combined (Figures 11-16). Appendix A provides descriptions of the queries and input sources (tables and queries) for the queries developed in the database.

Queries identified in the hierarchies as "Parameter" use values for the parameters Case, Origin, State, Mode, End Node, Regional Corridor, and Fuel Type in combination to retrieve specific sets of data for output. For each parameter requiring a value, the user may specify a distinct value or may specify "All." When "All" is specified, all possible values for the parameter will be retrieved. Specifying parameter values is discussed in more detail in Section 2.0, Database Forms.

Queries identified in the hierarchies with the initial characters "MT" create calculated values tables. The queries below the "MT" queries are run only when it is necessary to update the calculated values tables to incorporate updated or new source data. Data in the calculated values tables can be updated whenever a value in a related table changes. For example, if the number of kilometers from an origin through a state is updated, the calculated values tables storing the shipment kilometers and dose consequences also must be updated because they depend on that value. The method used to update data in the calculated values tables is discussed in more detail in Section 2.0, Database Forms.

The Outside NV query hierarchies (Figures 11 and 12) use input from and calculates values for all states in the database except Nevada. Both accident risk and incident-free dose consequence calculations are based on shipment kilometers (that is, the number of shipments multiplied by the number of kilometers that the shipments must travel to reach the Yucca Mountain disposal facility).

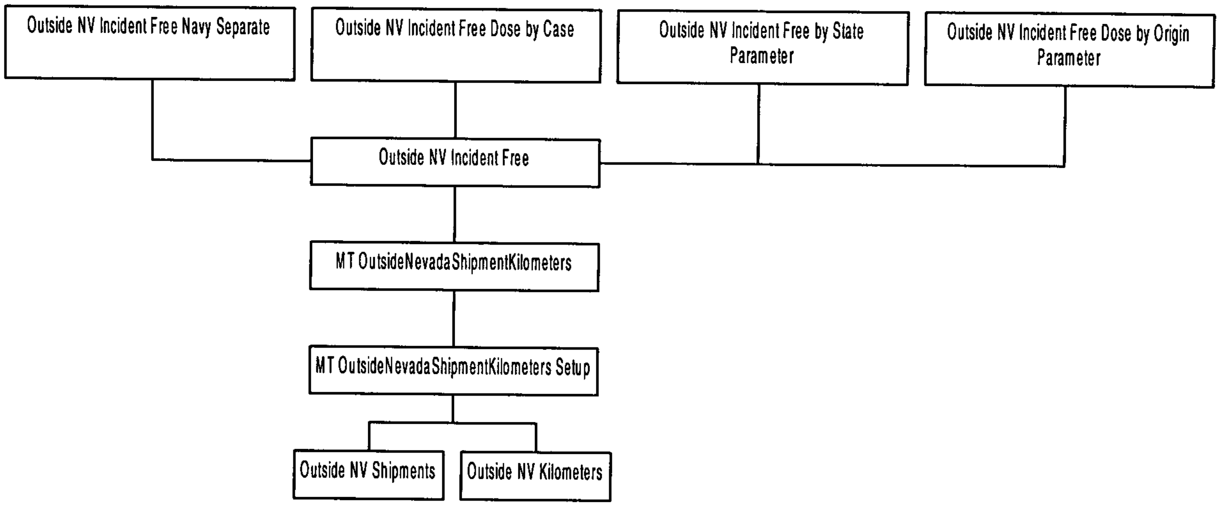


Figure 11. Outside NV Incident-Free Query Hierarchy

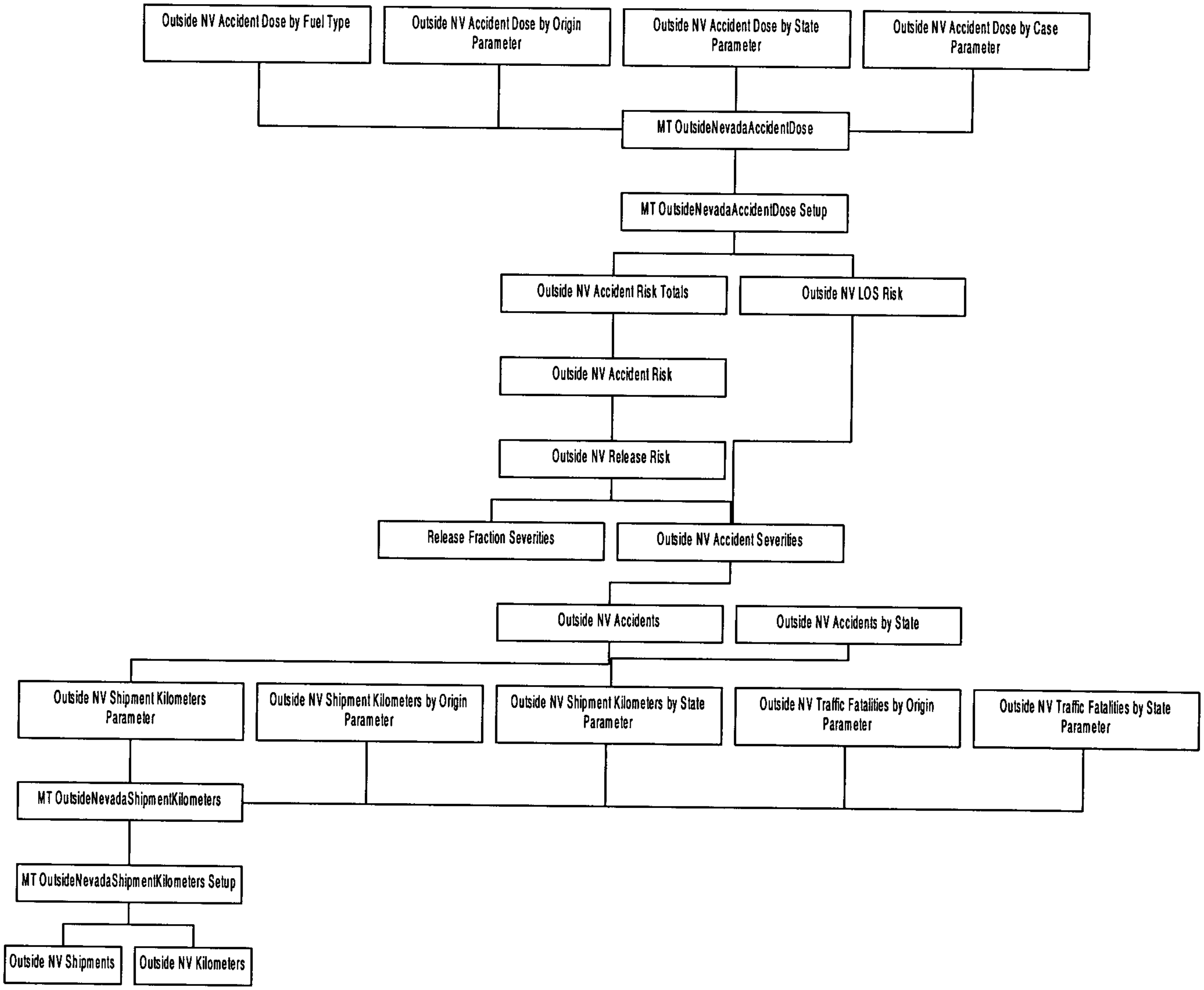


Figure 12. Outside NV Accident Query Hierarchy

The Nevada query hierarchies (Figures 13 and 14) use input from and calculate values for Nevada counties only, including the regional corridors. The distances within Nevada for the legal-weight truck mode and the rail mode to the rail end nodes are stored in the Kilometers table with all other state kilometer distances. The kilometer distances for the regional corridors from the rail end nodes to the disposal facility are stored in a separate table (Regional Corridors) because these distances are the same for all origins and do not need to be repeated for each origin. To allow dose risks for Nevada counties to be calculated separately from all other states, the shipment kilometers for Nevada counties for the legal-weight truck mode and rail mode to the rail end nodes are calculated separately from all other states. The NV to End Node Shipment Kilometers for the legal-weight truck mode and rail mode to the rail end nodes are then combined with the regional corridor shipment kilometers in a union query.

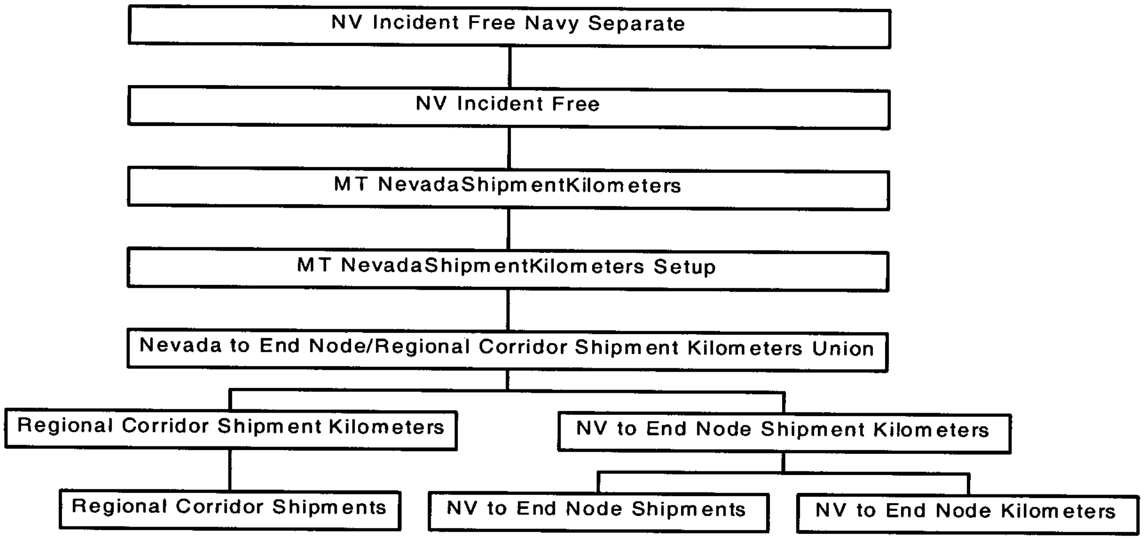


Figure 13. Nevada Incident-Free Query Hierarchy

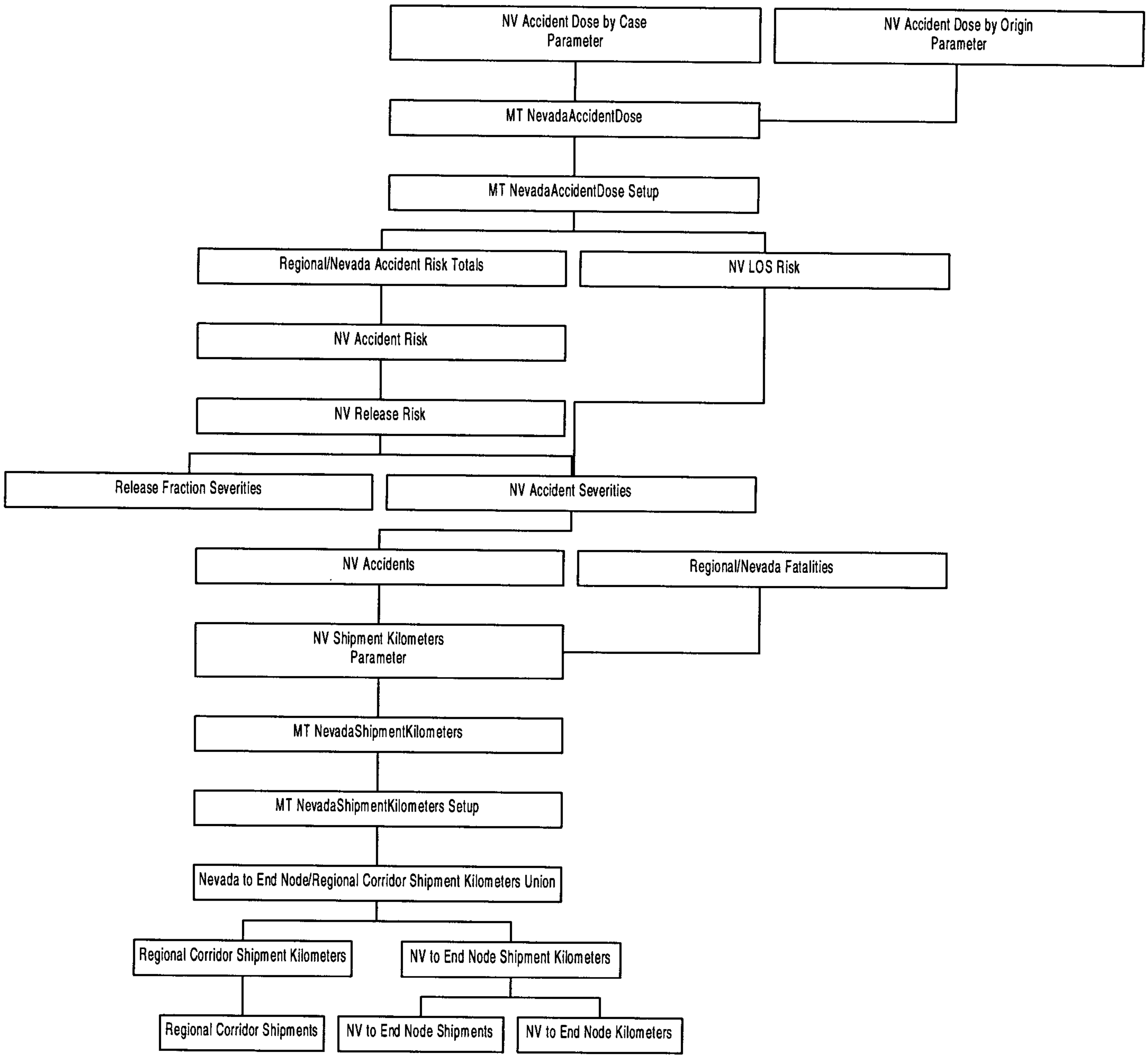


Figure 14. Nevada Accident Query Hierarchy

The Combined query hierarchies (Figures 15 and 16) combine the results from the Outside NV queries and the Nevada queries to produce results for all states in the database. Results in the Combined query hierarchies are reported using one of the ten regional alternatives; the one exception is the sites that do not have crane capacity for a rail cask and do not use rail as a transportation option are summed and reported as "Truck Only Sites."

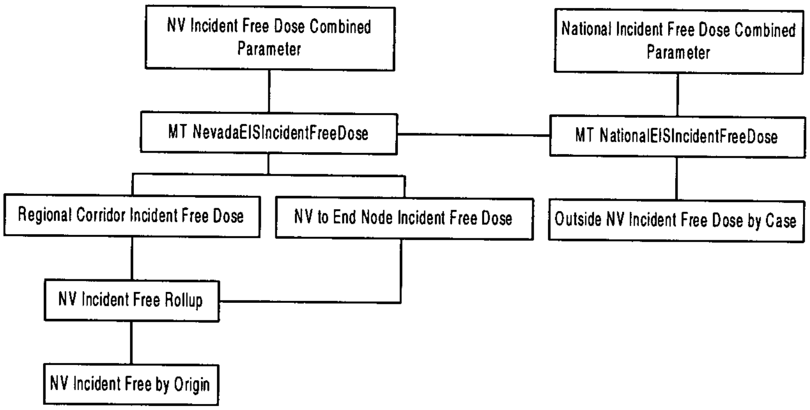


Figure 15. Combined Incident-Free Query Hierarchy

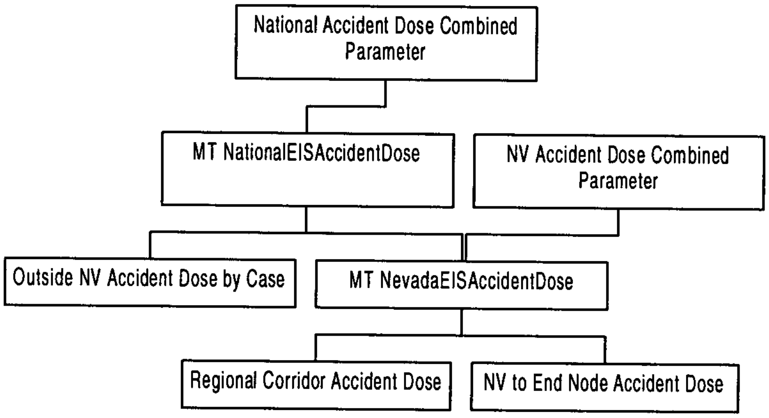


Figure 16. Combined Accident Query Hierarchy

5. SENSITIVITY ANALYSES

Seven databases were developed to analyze different routing schemes for the Mostly Truck Case and one database was developed analyze a different routing scheme for the Mostly Rail Case. Legal-weight truck routing goes through common locations such as Barstow, California (two cases); Needles, California (two cases); Wendover, Utah (two cases); and the intersection of I-15 and U.S. 95 (the "Spaghetti Bowl") in Las Vegas, Nevada (one case). Legal-weight truck routing was the only information changed in each of these sensitivity cases.

The names of the databases and their routing from the common location to the proposed repository site are as follows:

- Highway routes using U.S. 93 alternate from Wendover, Utah to U.S. 93 at Lages, Nevada to U.S. 6 at Ely, Nevada to NV 318 at Preston, Nevada to U.S. 93 at Hiko, Nevada to I-15 at Garnet, Nevada to the Northern beltway around Las Vegas to U.S. 95 to Yucca Mountain. (Truck A.mdb)

- Highway routes using U.S. 93 alternate from Wendover, Utah to U.S. 93 at Lages, Nevada to U.S. 6 at Ely, Nevada to U.S. 95 at Tonopah, Nevada to Yucca Mountain. (Truck B.mdb)

- Highway routes using I-15 from Barstow, California to CA 127 at Baker, California to NV 373 to U.S. 95 to Yucca Mountain. (Truck C.mdb)

- Highway routes using I-15 from Barstow, California to NV 160 at Arden, Nevada to U.S. 95 to Yucca Mountain. (Truck D.mdb)

- Highway routes using U.S. 95 from Needles, California to NV 164 at Searchlight, Nevada to I-15 at Nipton, California to CA 127 at Baker, California to NV 373 to U.S. 95 to Yucca Mountain. (Truck E.mdb)

- Highway routes using U.S. 95 from Needles, California to NV 164 at Searchlight, Nevada to I-15 at Nipton, California to NV 160 at Arden, Nevada to U.S. 95 to Yucca Mountain. (Truck F.mdb)

- Highway routes using I-15 to U.S. 95 in Las Vegas to Yucca Mountain. (Truck Spag.mdb)

Two additional databases were developed to analyze the sensitivity of the results to having inspections in every state (Inspections.mdb) and to having separate escorts in all population zones (Escorts.mdb).

6. REFERENCES

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APPENDIX A. QUERY DESCRIPTIONS TABLE

This table provides descriptions and the input sources (tables and queries) for queries developed in the database.

Query Name	Query Description	Input Tables/Queries
Barge Origins	Displays origins that use Barge mode.	Kilometers
EIS National Module 1	Combines and displays data from the National Incident Free Dose Combined and the National Accident Dose Combined queries, calculates Latent Cancer Fatalities, and presents the data in EIS format for Module 1.	National Incident Free Dose Combined, National Accident Dose Combined
EIS National Module 2	Combines and displays data from the National Incident Free Dose Combined and the National Accident Dose Combined queries, calculates Latent Cancer Fatalities, and presents the data in EIS format for Module 2.	National Incident Free Dose Combined, National Accident Dose Combined
EIS National Proposed Action	Combines and displays data from the National Incident Free Dose Combined and the National Accident Dose Combined queries, calculates Latent Cancer Fatalities, and presents the data in EIS format for the Proposed Action.	National Incident Free Dose Combined, National Accident Dose Combined
EIS NV Module 1	Combines and displays data from the NV Incident Free Dose Combined and the NV Accident Dose Combined queries, calculates Latent Cancer Fatalities, and presents the data in EIS format for Module 1.	NV Incident Free Dose Combined, NV Accident Dose Combined
EIS NV Module 2	Combines and displays data from the NV Incident Free Dose Combined and the NV Accident Dose Combined queries, calculates Latent Cancer Fatalities, and presents the data in EIS format for Module 2.	NV Incident Free Dose Combined, NV Accident Dose Combined
EIS NV Proposed Action	Combines and displays data from the NV Incident Free Dose Combined and the NV Accident Dose Combined queries, calculates Latent Cancer Fatalities, and presents the data in EIS format for the Proposed Action.	NV Incident Free Dose Combined, NV Accident Dose Combined
Heavy Haul Truck Origins	Displays origins that use Heavy Haul Truck mode.	Kilometers, Cases/Kilometers
Legal Weight Truck Only Origins	Displays origins that exclusively use Legal Weight Truck mode.	Kilometers, Cases/Kilometers

MT NationalEISAccidentDose	Sums the Outside NV Accident Dose by Cases and Nevada Accident Doses and makes the table NationalEISAccidentDose.	NevadaEISAccidentDose
MT NationalEISIncidentFreeDose	Sums the Outside NV Incident Free Dose by Cases and Nevada Incident Free Doses and makes the table NationalEISIncidentFreeDose.	NevadaEISIncidentFreeDose
MT NevadaAccidentDose	Makes the table NevadaAccidentDose.	MT NevadaAccidentDose Setup
MT NevadaAccidentDose Setup	Formats the Groundshine, Ingestion, Inhalation, Immersion, Resuspension, and Loss of Shielding Dose Risks in Nevada.	NV Accident Risk Totals, NV LOS Risk
MT NevadaEISAccidentDose	Sums the NV to End Node Accident Doses and Regional Corridor Accident Doses and makes the table NevadaEISAccidentDose.	Regional Corridor Accident Dose
MT NevadaEISIncidentFreeDose	Sums the NV to End Node Incident Free Doses and Regional Corridor Incident Free Doses and makes the table NevadaEISIncidentFreeDose.	Regional Corridor Incident Free Dose
MT NevadaShipmentKilometers	Makes the table NevadaShipmentKilometers.	MT NevadaShipmentKilometers Setup
MT NevadaShipmentKilometers Setup	Formats the NV to End Node and Regional Corridor Shipment Kilometers.	Nevada to End Node/Regional Corridor Shipment Kilometers Union
MT OutsideNevadaAccidentDose	Makes the table OutsideNevadaAccidentDose.	MT OutsideNevadaAccidentDose Setup
MT OutsideNevadaAccidentDose Setup	Formats the Groundshine, Ingestion, Inhalation, Immersion, Resuspension, and Loss of Shielding Dose Risks outside Nevada.	Outside NV Accident Risk Totals, Outside NV LOS Risk
MT OutsideNevadaShipmentKilometers	Makes the table OutsideNevadaShipmentKilometers.	MT OutsideNevadaShipmentKilometers Setup
MT OutsideNevadaShipmentKilometers Setup	Calculates shipment kilometers outside Nevada.	Outside NV Shipments, Outside NV Kilometers
National Accident Dose Combined	Displays the Accident Dose Risks Combined (Origin to repository) for the selected Case.	NationalEISAccidentDose
National Incident Free Dose Combined	Displays the Incident Free Dose Risks (Origin to repository) by Case and Corridor for a selected Case.	NationalEISIncidentFreeDose
Nevada to End Node/Regional Corridor Shipment Kilometers Union	Combines the Regional Corridor Shipment Kilometers with the Nevada to End Node Shipment Kilometers.	NV to End Node Shipment Kilometers, Regional Corridor Shipment Kilometers
Outside NV Accident Dose Rollup	Sums the Accident Dose Risks outside Nevada by Case, Mode, and End Node for the selected Case, Mode, and End Node.	OutsideNevadaAccidentDose

Outside NV Accident Dose by Fuel Type	Sums the Accident Dose Risks outside Nevada by Fuel Type, Mode, and Case for the selected Fuel Type and Case.	OutsideNevadaAccidentDose
NV Accident Dose by Case	Sums the Accident Dose Risks in Nevada by Case, Mode, and Corridor for the selected Case, Mode, and Corridor.	NevadaAccidentDose
NV Accident Dose by Origin	Sums the Accident Dose Risks in Nevada by Origin, Corridor, Case, Mode, and Fuel Type for the selected Origin, Case, Corridor, and Fuel Type.	NevadaAccidentDose
NV Accident Dose Combined	Displays the Nevada Accident Dose Risks by Case and Corridor for the selected Case.	NevadaEISAccidentDose
NV Accident Risk	Calculates the Accident Dose Risk in Nevada by Origin, State, Corridor, Cask, Case, Fuel Type, Mode, End Node, and Isotope.	NV Release Risk, States, Food Transfer Factors, Isotopes, Groups, Kilometers, Regional Corridors
NV Accident Risk Totals	Sums the Accident Dose Risk in Nevada by Origin, State, Corridor, Case, Fuel Type, Mode, and End Node.	NV Accident Risk
NV Accident Severities	Calculates Accident Severities in Nevada by Origin, State, Corridor, Cask, Case, Fuel Type, Mode, and End Node.	NV Accidents, Casks/Modes
NV Accidents	Calculates Accidents in Nevada by Origin, State, Corridor, Case, Mode, End Node, Fuel Type, and Cask.	NV Shipment Kilometers, Accident Rates
NV Fatalities	Calculates the Nevada Traffic Fatalities by Corridor and Fuel Type.	NV Shipment Kilometers, Accident Rates
NV Incident Free	Calculates the doses for Offlink population, Onlink population, Stops, Public Classification Stops, Public Far Field, Workers, Worker Classification Stops, Worker Overnight Stops, Escorts, Escort Stops, Pollution Health Effects, Escort Pollution Health Effects, Traffic Fatalities, and Escort Traffic Fatalities by Origin, State, Corridor, Case, Mode, and Fuel Type for all segments in Nevada.	NevadaShipmentKilometers, Kilometers, Accident Rates, Origins, States, Regional Corridors, Unit Risk Factors, End Nodes, Fuel Types

NV Incident Free by Origin	Calculates the doses for Offlink population, Onlink population, Stops, Public Classification Stops, Public Far Field, Workers, Worker Classification Stops, Worker Overnight Stops, Escorts, Escort Stops, Pollution Health Effects, Escort Pollution Health Effects, Traffic Fatalities, and Escort Traffic Fatalities by Origin, Corridor, Case, Mode, and Fuel Type for all segments in Nevada.	NevadaShipmentKilometers, Kilometers, Regional Corridors, Accident Rates, End Nodes, Fuel Types, Origins, States, Unit Risk Factors
NV Incident Free Dose Combined	Displays the Nevada Incident Free Dose Risks by Case and Corridor for the selected Case.	NevadaEISIncidentFreeDose
NV Incident Free Navy Separate	Sums the Nevada Incident Free Dose Risks by Case, Mode, and Corridor and displays Navy risks separately.	NV Incident Free
NV Incident Free Rollup	Sums the dose risk calculated in the NV Incident Free by Origin query by Case and Corridor.	NV Incident Free by Origin
NV LOS Risk	Calculates and sums Loss of Shielding Risk in Nevada by Origin, State, Corridor, Case, Fuel Type, Mode, and End Node.	NV Accident Severities, Kilometers, Regional Corridors, States
NV Release Risk	Calculates the Release Risks from an accident in Nevada by Origin, State, Corridor, Cask, Case, Fuel Type, Mode, End Node, Isotope, and Group.	NV Accident Severities, Release Fraction Severities
NV Shipment Kilometers	Calculates the Shipment Kilometers in Nevada by Origin, State, Corridor, Case, Mode, End Node, Fuel Type, and Cask for the selected Case, Origin, Corridor, and Fuel Type.	NevadaShipmentKilometers
NV to End Node Accident Dose	Sums the Accident Dose Risks in Nevada for segments from the Nevada border to the rail end nodes by Case and End Node.	NevadaAccidentDose
NV to End Node Incident Free Dose	Sums the Incident Free Dose Risks in Nevada for segments from the Nevada border to the rail end nodes by Case and End Node.	NV Incident Free by Origin Rollup
NV to End Node Kilometers	Sums the Kilometers in Nevada not including the Regional Corridors by Origin, State, Case, Mode, and End Node.	Kilometers, Cases/Kilometers
NV to End Node Shipment Kilometers	Calculates the Shipment Kilometers in Nevada not including the Regional Corridors by Origin, State, Case, Mode, End Node, Fuel Type, and Cask.	NV to End Node Shipments, NV to End Node Kilometers

NV to End Node Shipments	Sums the Shipments in Nevada by Origin, State, Cask, Fuel Type, Mode, End Node, and Case.	Casks, Shipments, Cases/Shipments, Pools, Kilometers, Cases/Kilometers, Casks/Modes
Outside NV Accident Dose by Case	Sums the Accident Dose Risks outside Nevada by Case and End Node.	OutsideNevadaAccidentDose
Outside NV Accident Dose by Fuel Type	Sums the Accident Dose Risks outside Nevada Fuel Type, Mode, and Case for the selected Fuel Type and Case.	OutsideNevadaAccidentDose
Outside NV Accident Dose by Origin	Sums the Accident Dose Risks outside Nevada by Origin, Case, Mode, End Node, and Fuel Type for the selected Case, Mode, End Node, Origin, and Fuel Type.	OutsideNevadaAccidentDose
Outside NV Accident Dose by State	Sums the Accident Dose Risks outside Nevada by State, Case, and End Node.	OutsideNevadaAccidentDose
Outside NV Accident Dose by State and Fuel Type	Sums the Accident Dose Risks outside Nevada by State, Case, Mode, End Node, and Fuel Type for the selected Case, Mode, End Node, State, and Fuel Type.	OutsideNevadaAccidentDose
Outside NV Accident Dose Rollup	Sums the Accident Dose Risks outside Nevada by Case, Mode, and End Node for the selected Case, Mode, and End Node.	OutsideNevadaAccidentDose
Outside NV Accident Risk	Calculates the Accident Dose Risk outside Nevada by Origin, State, Cask, Case, Fuel Type, Mode, End Node, and Isotope.	Outside NV Release Risk, States, Food Transfer Factors, Isotopes, Groups, Kilometers
Outside NV Accident Risk Totals	Sums the Accident Dose Risk outside Nevada by Origin, State, Case, Fuel Type, Mode, and End Node.	Outside NV Accident Risk
Outside NV Accident Severities	Calculates Accident Severities outside Nevada by Origin, State, Cask, Case, Fuel Type, Mode, and End Node.	Outside NV Accidents, Accident Probabilities
Outside NV Accident Severities 5&6	Sums Severity 5 and 6 Accidents by Case, Fuel Type, Mode, and End Node.	Outside NV Accident Severities
Outside NV Accidents	Calculates Accidents outside Nevada by Origin, State, Case, Mode, End Node, Fuel Type, and Cask,.	Outside NV Shipment Kilometers, Accident Rates
Outside NV Accidents by State	Calculates Accidents outside Nevada by State, Case, Mode, End Node, Fuel Type, and Cask.	Outside NV Shipment Kilometers by State, Accident Rates

Outside NV Incident Free	Calculates the doses for Offlink population, Onlink population, Stops, Public Classification Stops, Public Far Field, Workers, Worker Classification Stops, Escorts, Escort Stops, Pollution Health Effects, Escort Pollution Health Effects, Traffic Fatalities, and Escort Traffic Fatalities by Origin, State, Case, Mode, and End Node for all segments outside Nevada.	OutsideNevadaShipmentKilometers, Kilometers, Origins, States, Accident Rates, Unit Risk Factors, Fuel Types
Outside NV Incident Free by State	Sums the Incident Free Dose Risks outside Nevada by State, Case, Mode, and End Node for the selected Case, State, Mode, and End Node.	Outside NV Incident Free
Outside NV Incident Free Dose by Case	Sums the Incident Free Dose Risks outside Nevada by Case and End Node.	Outside NV Incident Free
Outside NV Incident Free Dose by Origin	Sums the Incident Free Dose Risks outside Nevada by Origin, Case, Mode, and End Node for the selected Case, Origin, Mode, and End Node.	Outside NV Incident Free
Outside NV Incident Free Navy Separate	Sums the Incident Free Dose Risks by outside Nevada by Case, Mode, and End Node and displays Navy risks separately.	Outside NV Incident Free
Outside NV Kilometers	Sums the Kilometers outside Nevada by Origin, State, Case, Mode, and End Node.	Kilometers, Cases/Kilometers
Outside NV LOS Risk	Calculates and sums Loss of Shielding Risk outside Nevada by Origin, State, Case, Fuel Type, Mode, and End Node.	Outside NV Accident Severities, Kilometers, States
Outside NV Release Risk	Calculates the Release Risks from an accident outside Nevada by Origin, State, Cask, Case, Fuel Type, Mode, End Node, Isotope, and Group.	Outside NV Accident Severities, Release Fraction Severities
Outside NV Shipment Kilometers	Calculates the Shipment Kilometers outside Nevada by Origin, State, Case, Mode, End Node, Fuel Type, and Cask for the selected Case, Mode, End Node, State, Origin, and Fuel Type.	OutsideNevadaShipmentKilometers
Outside NV Shipment Kilometers by Origin	Sums the Shipment Kilometers outside Nevada by Origin, Case, Mode, End Node, Fuel Type, and Cask for the selected Case, Mode, End Node, Origin, and Fuel Type.	OutsideNevadaShipmentKilometers

Outside NV Shipment Kilometers by State	Sums the Shipment Kilometers outside Nevada by State, Case, Mode, End Node, Fuel Type, and Cask for the selected Case, Mode, End Node, State, and Fuel Type.	OutsideNevadaShipmentKilometers
Outside NV Shipments	Sums the shipments outside Nevada by Origin, State, Cask, Case, Mode, End Node, and Fuel Type.	Shipments, Cases/Shipments, Cases/Kilometers, Kilometers, Pools, Casks, Casks/Modes
Outside NV Traffic Fatalities by Case	Sums Traffic Fatalities outside Nevada by Case, Fuel Type, Mode, and End Node.	Outside NV Traffic Fatalities by Origin
Outside NV Traffic Fatalities by Origin	Sums the Traffic Fatalities outside Nevada by Origin, Case, Mode, End Node, and Fuel Type for the selected Case, Mode, End Node, Origin, and Fuel Type.	OutsideNevadaShipmentKilometers, Accident Rates
Outside NV Traffic Fatalities by State	Calculates Traffic Fatalities outside Nevada by State, Case, Mode, End Node, and Fuel Type.	OutsideNevadaShipmentKilometers, Accident Rates
Regional Corridor Accident Dose	Sums the Regional Corridor Accident Doses by Case and Corridor.	NevadaAccidentDose
Regional Corridor Incident Free Dose	Sums the Regional Corridor Incident Free Dose Risks by Case and Corridor.	NV Incident Free Rollup
Regional Corridor Shipment Kilometers	Calculates shipment kilometers for Regional Corridors.	Regional Corridor Shipments, Regional Corridors
Regional Corridor Shipments	Sums the Shipments using Regional Corridors in Nevada by Origin, State, Cask, Case, Fuel Type, Mode, and End Node.	Shipments, Cases/Shipments, Pools, Cases/Kilometers, Kilometers, Casks, Casks/Modes
Release Fraction Severities	Calculates Release Fractions for 6 severity categories for nuclear waste stored 14 years.	Casks, Curies per Assembly, Isotopes, Release Fractions
Note: In the read-only versions of the database, the MT queries are disabled.		

APPENDIX B. CALCULATIONS PERFORMED BY DATABASE QUERIES

The tables in this appendix provide representative examples of the query names, query fields, equations developed in the queries, and a description of the elements that make up the equations. If there are any null (blank) values in an equation that uses addition, the result will be null. The function Nz() is used to replace null values with zeros so that values can be added together.

Table B-1. Incident-Free Offlink Public Dose Calculation

Query Name	Query Field	Equation Used	Description
MT OutsideNevadaShipment Kilometers Setup	Rural Proposed Action	Nz([Proposed Action],0)*Nz([Rural Kilometers],0)	Calculates Rural Shipment Kilometers Proposed Action = Proposed action shipments Rural Kilometers = Rural Kilometers
Outside NV Incident Free	Off Link Rural Proposed Action	Sum(Nz([Rural Proposed Action],0) *[Rural Density]*[PopEscalationFactor] *([TI]/14) *IIf([OutsideNevadaShipmentKilometers].[OriginID]<>84,[OffLink Rural],[OffLinkNavy Rural]))	Calculates Rural Off Link Public Dose Rural Proposed Action = Rural Shipment Kilometers calculated in MT OutsideNevadaShipmentKilometers Setup Rural Density = Rural Population density PopEscalationFactor = State Population Escalation Factor TI = Transportation Index of Fuel Type OriginID 84 = Navy; If origin does not equal 84, use normal Off Link Rural Unit Risk Factor (OffLink Rural), else use Navy Off Link Rural Unit Risk Factor (OffLinkNavy Rural) OffLink Rural = Unit Risk Factor Off Link Public for use in rural zones for non-Navy shipments OffLinkNavy Rural = Unit Risk Factor Off Link Public for use in rural zones for Navy shipments
Outside NV Incident Free Navy Separate	Proposed Action Off Link Public	Sum(IIf([Outside NV Incident Free].[OriginID]<>84,Nz([Off Link Rural Proposed Action],0)+Nz([Off Link Suburban Proposed Action],0)+Nz([Off Link Urban Proposed Action],0),0))	Calculates the Total Off Link Public Dose for non-Navy shipments Sums the Rural, Suburban and Urban Proposed Action Off Link Public Doses for non-Navy shipments
Outside NV Incident Free Navy Separate	Navy Proposed Action Off Link Public	Sum(IIf([Outside NV Incident Free].[OriginID]=84,Nz([Off Link Rural Proposed Action],0)+Nz([Off Link Suburban Proposed Action],0)+Nz([Off Link Urban Proposed Action],0),0))	Calculates the Total Off Link Public Dose for Navy shipments Sums the Rural, Suburban and Urban Proposed Action Off Link Public Doses for Navy shipments

Table B-2. Incident-Free Onlink Public Dose Calculation

Query Name	Query Field	Equation Used	Description
MT OutsideNevadaShipment Kilometers Setup	Rural Proposed Action	Nz([Proposed Action],0)*Nz([Rural Kilometers],0)	Calculates Rural Shipment Kilometers Proposed Action = Proposed action shipments Rural Kilometers = Rural Kilometers
Outside NV Incident Free	On Link Rural Proposed Action	Sum(Nz([Rural Proposed Action],0) *([TI]/14) *IIf([OutsideNevadaShipmentKilometers].[OriginID]<>84,[OnLink Rural],[OnLinkNavy Rural]))	Calculates Rural On Link Public Dose Rural Proposed Action = Rural Shipment Kilometers calculated in MT OutsideNevadaShipmentKilometers Setup TI = Transportation Index of Fuel Type OriginID 84 = Navy; If origin does not equal 84, use normal On Link Rural Unit Risk Factor (OnLink Rural), else use Navy On Link Rural Unit Risk Factor (OnLinkNavy Rural) OnLink Rural = Unit Risk Factor On Link Public for use in rural zones for non-Navy shipments OnLinkNavy Rural = Unit Risk Factor On Link Public for use in rural zones for Navy shipments
Outside NV Incident Free Navy Separate	Proposed Action On Link Public	Sum(IIf([Outside NV Incident Free].[OriginID]<>84,Nz([On Link Rural Proposed Action],0)+Nz([On Link Suburban Proposed Action],0)+Nz([On Link Urban Proposed Action],0),0))	Calculates the Total On Link Public Dose for non-Navy shipments Sums the Rural, Suburban and Urban Proposed Action On Link Public Doses for non-Navy shipments
Outside NV Incident Free Navy Separate	Navy Proposed Action On Link Public	Sum(IIf([Outside NV Incident Free].[OriginID]=84,Nz([On Link Rural Proposed Action],0)+Nz([On Link Suburban Proposed Action],0)+Nz([On Link Urban Proposed Action],0),0))	Calculates the Total On Link Public Dose for Navy shipments Sums the Rural, Suburban and Urban Proposed Action On Link Public Doses for Navy shipments

Table B-3. Incident-Free Stops Public Dose and Total Public Dose Calculation (1 of 2)

Query Name	Query Field	Equation Used	Description
MT OutsideNevadaShipment Kilometers Setup	Rural Proposed Action	Nz([Proposed Action],0)*Nz([Rural Kilometers],0)	Calculates Rural Shipment Kilometers Proposed Action = Proposed action shipments Rural Kilometers = Rural Kilometers
Outside NV Incident Free	Stops Rural Proposed Action	Sum(Nz([Rural Proposed Action],0) *[Rural Density] *[PopEscalationFactor]*([TI]/14) *IIf([OutsideNevadaShipmentKilometers].[OriginID] <>84,[Stops Rural],[StopsNavy Rural]))	Calculates normal Rural Stops Public Dose Rural Proposed Action = Rural Shipment Kilometers calculated in MT OutsideNevadaShipmentKilometers Setup Rural Density = Rural Population density PopEscalationFactor = State Population Escalation Factor TI = Transportation Index of Fuel Type OriginID 84 = Navy; If origin does not equal 84, use normal Stops Rural Unit Risk Factor (Stops Rural), else use Navy Stops Rural Unit Risk Factor (StopsNavy Rural) Stops Rural = Unit Risk Factor Stops Public for use in rural zones for non-Navy shipments StopsNavy Rural = Unit Risk Factor Stops Public for use in rural zones for Navy shipments
Outside NV Incident Free	Public Classification Stops Proposed Action	Sum(IIf([OutsideNevadaShipmentKilometers].[StateID]=[Origins].[StateID], [Proposed Action]*[Suburban Density]*[PopEscalationFactor] *IIf([OutsideNevadaShipmentKilometers].[OriginID] <>84,[PubClassStops], [PubClassStopsNavy]),0))	Calculates Suburban Classification Stops Public Dose in the origin state Proposed Action = Proposed action shipments Suburban Density = Suburban Population density PopEscalationFactor = State Population Escalation Factor OriginID 84 = Navy; If origin does not equal 84, use normal Public Classification Stops Unit Risk Factor (PubClassStops), else use Navy Public Stops Unit Risk Factor (PubClassStopsNavy) PubClassStops = Unit Risk Factor Classification Stops Public for non-Navy shipments PubClassStopsNavy = Unit Risk Factor Classification Stops Public for Navy shipments
Outside NV Incident Free	Public Far Field Rural Proposed Action	Sum(Nz([Rural Proposed Action],0)*Nz([PubFarField Rural],0))	Calculates Rural Public Far Field Dose Rural Proposed Action = Rural Shipment Kilometers calculated in MT OutsideNevadaShipmentKilometers Setup PubFarField Rural = Unit Risk Factor Far Field Public

Table B-3. Incident-Free Stops Public Dose and Total Public Dose Calculation (2 of 2)

Query Name	Query Field	Equation Used	Description
Outside NV Incident Free Navy Separate	Proposed Action Stops Public	Sum(IIf([Outside NV Incident Free].[OriginID]<>84,Nz([Stops Rural Proposed Action],0)+Nz([Stops Suburban Proposed Action],0)+Nz([Stops Urban Proposed Action],0)+Nz([Public Classification Stops Proposed Action],0)+Nz([Public Far Field Rural Proposed Action],0)+Nz([Public Far Field Suburban Proposed Action],0)+Nz([Public Far Field Urban Proposed Action],0),0))	Calculates Total Public Dose for non-Navy shipments Sums the Rural, Suburban and Urban Proposed Action Stops Public Doses, the Proposed Action Classification Stops Public Dose, and the Rural, Suburban and Urban Proposed Action Far Field Public Doses for non-Navy shipments
Outside NV Incident Free Navy Separate	Navy Proposed Action Stops	Sum(IIf([Outside NV Incident Free].[OriginID]=84,Nz([Stops Rural Proposed Action],0)+Nz([Stops Suburban Proposed Action],0)+Nz([Stops Urban Proposed Action],0)+Nz([Public Classification Stops Proposed Action],0)+Nz([Public Far Field Rural Proposed Action],0)+Nz([Public Far Field Suburban Proposed Action],0)+Nz([Public Far Field Urban Proposed Action],0),0)	Calculates Total Public Dose for Navy shipments Sums the Rural, Suburban and Urban Proposed Action Stops Public Doses, the Proposed Action Classification Stops Public Dose, and the Rural, Suburban and Urban Proposed Action Far Field Public Doses for Navy shipments

Table B-4. Incident-Free Worker Dose Calculation (1 of 2)

Query Name	Query Field	Equation Used	Description
MT OutsideNevadaShipmentKilometers Setup	Rural Proposed Action	Nz([Proposed Action],0)*Nz([Rural Kilometers],0)	Calculates Rural Shipment Kilometers Proposed Action = Proposed action shipments Rural Kilometers = Rural Kilometers
Outside NV Incident Free	Worker Rural Proposed Action	Sum(Nz([Rural Proposed Action],0) *([TI]/14) *IIf([OutsideNevadaShipmentKilometers].[OriginID]<> 84,[Worker Rural],[WorkerNavy Rural]))	Calculates Rural Worker Dose Rural Proposed Action = Rural Shipment Kilometers calculated in MT OutsideNevadaShipmentKilometers Setup TI = Transportation Index of Fuel Type OriginID 84 = Navy; If origin does not equal 84, use normal Worker Rural Unit Risk Factor (Worker Rural), else use Navy Worker Rural Unit Risk Factor (WorkerNavy Rural) Worker Rural = Unit Risk Factor Worker for use in rural zones for non-Navy shipments WorkerNavy Rural = Unit Risk Factor Worker for use in rural zones for Navy shipments
Outside NV Incident Free	Worker Stops Rural Proposed Action	Sum([Rural Proposed Action] *IIf([OutsideNevadaShipmentKilometers].[OriginID]<> 84,[WorkerStops Rural],[WorkerStopsNavy Rural]))	Calculates Rural Worker Stops Dose Rural Proposed Action = Rural Shipment Kilometers calculated in MT OutsideNevadaShipmentKilometers Setup OriginID 84 = Navy; If origin does not equal 84, use normal Worker Rural Stops Unit Risk Factor (WorkerStops Rural), else use Navy Worker Stops Rural Unit Risk Factor (WorkerStopsNavy Rural) WorkerStops Rural = Unit Risk Factor Worker Stops for use in rural zones for non-Navy shipments WorkerStopsNavy Rural = Unit Risk Factor Worker Stops for use in rural zones for Navy shipments
Outside NV Incident Free	Worker Classification Stops Proposed Action	Sum(IIf([OutsideNevadaShipmentKilometers].[StateID] =[Origins].[StateID], [Proposed Action],0) *IIf([OutsideNevadaShipmentKilometers].[OriginID]<> 84,[WorkerClassStops], [WorkerClassStopsNavy]))	Calculates Classification Stops Worker Dose in the origin state Proposed Action = Proposed action shipments OriginID 84 = Navy; If origin does not equal 84, use normal Worker Classification Stops Unit Risk Factor (WorkerClassStops), else use Navy WorkerStops Unit Risk Factor (WorkerClassStopsNavy) WorkerClassStops = Unit Risk Factor Classification Stops Worker for non-Navy shipments WorkerClassStopsNavy = Unit Risk Factor Classification Stops Worker for Navy shipments

Table B-4. Incident-Free Worker Dose Calculation (2 of 2)

Query Name	Query Field	Equation Used	Description
Outside NV Incident Free Navy Separate	Proposed Action Worker	Sum(IIf([Outside NV Incident Free].[OriginID]<>84,Nz([Worker Rural Proposed Action],0)+Nz([Worker Suburban Proposed Action],0)+Nz([Worker Urban Proposed Action],0)+Nz([Worker Stops Rural Proposed Action],0)+Nz([Worker Stops Suburban Proposed Action],0)+Nz([Worker Stops Urban Proposed Action],0)+Nz([Worker Classification Stops Proposed Action],0),0))	Calculates the Total Worker Dose for non-Navy shipments Sums the Rural, Suburban, and Urban Worker Dose and the Rural, Suburban, and Urban Worker Stops Dose, and the Worker Classification Stops Dose.
Outside NV Incident Free Navy Separate	Navy Proposed Action Worker	Sum(IIf([Outside NV Incident Free].[OriginID]=84,Nz([Worker Rural Proposed Action],0)+Nz([Worker Suburban Proposed Action],0)+Nz([Worker Urban Proposed Action],0)+Nz([Worker Stops Rural Proposed Action],0)+Nz([Worker Stops Suburban Proposed Action],0)+Nz([Worker Stops Urban Proposed Action],0)+Nz([Worker Classification Stops Proposed Action],0),0))	Calculates the Total Worker Dose for Navy shipments Sums the Rural, Suburban, and Urban Worker Dose and the Rural, Suburban, and Urban Worker Stops Dose, and the Worker Classification Stops Dose for Navy shipments.

Table B-5. Incident-Free Escort Dose Calculation (1 of 2)

Query Name	Query Field	Equation Used	Description
MT OutsideNevadaShipmentKilometers Setup	Rural Proposed Action	Nz([Proposed Action],0)*Nz([Rural Kilometers],0)	Calculates Rural Shipment Kilometers Proposed Action = Proposed action shipments Rural Kilometers = Rural Kilometers
Outside NV Incident Free	Escorts Rural Proposed Action	Sum([Rural Proposed Action]*([TI]/14) *IIf([OutsideNevadaShipmentKilometers].[OriginID] <>84,[WorkerEscorts Rural],[WorkerEscortsNavy Rural]))	Calculates Rural Escort Dose Rural Proposed Action = Rural Shipment Kilometers calculated in MT OutsideNevadaShipmentKilometers Setup TI = Transportation Index of Fuel Type OriginID 84 = Navy; If origin does not equal 84, use normal Escort Rural Unit Risk Factor (WorkerEscort Rural), else use Navy Escort Rural Unit Risk Factor (WorkerEscortsNavy Rural) WorkerEscorts Rural = Unit Risk Factor Worker Escorts for use in rural zones for non-Navy shipments WorkerEscortsNavy Rural = Unit Risk Factor Worker Escorts for use in rural zones for Navy shipments
Outside NV Incident Free	Escorts Stops Rural Proposed Action	Sum([Rural Proposed Action]*([TI]/14) *IIf([OutsideNevadaShipmentKilometers].[OriginID] <>84,[WorkerEscortsStops Rural],[WorkerEscortsStopsNavy Rural]))	Calculates Rural Escort Stops Dose Rural Proposed Action = Rural Shipment Kilometers calculated in MT OutsideNevadaShipmentKilometers Setup TI = Transportation Index of Fuel Type OriginID 84 = Navy; If origin does not equal 84, use normal Escort Stops Rural Unit Risk Factor (WorkerEscortStops Rural), else use Navy Escort Rural Unit Risk Factor (WorkerEscortsStopsNavy Rural) WorkerEscortsStops Rural = Unit Risk Factor Worker Escorts Stops for use in rural zones for non-Navy shipments WorkerEscortsStopsNavy Rural = Unit Risk Factor Worker Escorts Stops for use in rural zones for Navy shipments
Outside NV Incident Free	Escorts Stops Other Rural Proposed Action	Sum([Rural Proposed Action]*([TI]/14) *IIf([OutsideNevadaShipmentKilometers].[OriginID] <>84,0, [WorkerEscortsStopsNavy Other Rural]))	Calculates Rural Escort Stops Other Dose for Navy shipments Rural Proposed Action = Rural Shipment Kilometers calculated in MT OutsideNevadaShipmentKilometers Setup TI = Transportation Index of Fuel Type OriginID 84 = Navy; If origin does not equal 84, use 0, else use Navy Escort Other Rural Unit Risk Factor (WorkerEscortsStopsNavyOther Rural) WorkerEscortsStopsOtherNavy Rural = Unit Risk Factor Worker Escorts Stops Other for use in rural zones for Navy shipments

Table B-5. Incident-Free Escort Dose Calculation (2 of 2)

Query Name	Query Field	Equation Used	Description
Outside NV Incident Free Navy Separate	Proposed Action Escorts	Sum(IIf([Outside NV Incident Free].[OriginID]<>84,Nz([Escorts Rural Proposed Action],0)+Nz([Escorts Suburban Proposed Action],0)+Nz([Escorts Urban Proposed Action],0)+Nz([Escorts Stops Rural Proposed Action],0)+Nz([Escorts Stops Suburban Proposed Action],0)+Nz([Escorts Stops Urban Proposed Action],0),0))	Calculates total Escort Dose for non-Navy shipments Sums the Rural, Suburban, and Urban Escort Doses and the Rural, Suburban, and Urban Escort Stops Doses for non-Navy shipments.
Outside NV Incident Free Navy Separate	Navy Proposed Action Escorts	Sum(IIf([Outside NV Incident Free].[OriginID]=84,Nz([Escorts Rural Proposed Action],0)+Nz([Escorts Suburban Proposed Action],0)+Nz([Escorts Urban Proposed Action],0)+Nz([Escorts Stops Rural Proposed Action],0)+Nz([Escorts Stops Suburban Proposed Action],0)+Nz([Escorts Stops Urban Proposed Action],0)+Nz([Escorts Stops Other Rural Proposed Action],0)+Nz([Escorts Stops Other Suburban Proposed Action],0)+Nz([Escorts Stops Other Urban Proposed Action],0),0))	Calculates total Escort Dose for Navy shipments Sums the Rural, Suburban, and Urban Escort Doses, the Rural, Suburban, and Urban Escort Stops Doses, and the Rural, Suburban, and Urban Escort Stops Other Doses for Navy shipment.

Table B-6. Incident-Free Pollution Health Effects Calculation

Query Name	Query Field	Equation Used	Description
MT OutsideNevadaShipment Kilometers Setup	Rural Proposed Action	Nz([Proposed Action],0)*Nz([Rural Kilometers],0)	Calculates Rural Shipment Kilometers Proposed Action = Proposed action shipments Rural Kilometers = Rural Kilometers
Outside NV Incident Free	10 micron Pollution Rural Proposed Action	10 micron Pollution Rural Proposed Action: Sum(Nz([Rural Proposed Action],0)*[PollutionEff10 Rural]*[Rural Density]*[PopEscalationFactor]*2)	Calculates the Rural Pollution Health Effects Rural Proposed Action = Rural Shipment Kilometers calculated in MT OutsideNevadaShipmentKilometers Setup PollutionEff10 Rural = Pollution Health Effects Unit Risk Factor used in Rural Multiply by 2 for return trip
Outside NV Incident Free Navy Separate	10 micron Proposed Action Pollution	Sum(IIf([Outside NV Incident Free].[OriginID]<>84,Nz([10 micron Pollution Rural Proposed Action],0)+Nz([10 micron Pollution Suburban Proposed Action],0)+Nz([10 micron Pollution Urban Proposed Action],0),0))	Calculates the Total Pollution Health Effects for non-Navy shipments Sums the Rural, Suburban, and Urban Pollution Health Effects for non-Navy shipments
Outside NV Incident Free Navy Separate	Navy 10 micron Proposed Action Pollution	Sum(IIf([Outside NV Incident Free].[OriginID]=84,Nz([10 micron Pollution Rural Proposed Action],0)+Nz([10 micron Pollution Suburban Proposed Action],0)+Nz([10 micron Pollution Urban Proposed Action],0),0))	Calculates the Total Pollution Health Effects for Navy shipments Sums the Rural, Suburban, and Urban Pollution Health Effects for Navy shipments

Table B-7. Incident-Free Escort Pollution Health Effects Calculation

Query Name	Query Field	Equation Used	Description
MT OutsideNevadaShipment Kilometers Setup	Rural Proposed Action	Nz([Proposed Action],0)*Nz([Rural Kilometers],0)	Calculates Rural Shipment Kilometers Proposed Action = Proposed action shipments Rural Kilometers = Rural Kilometers
Outside NV Incident Free	Escorts Pollution Rural Proposed Action	Escorts Pollution Rural Proposed Action: Sum(Nz([Rural Proposed Action],0)* [Rural Density]*[PopEscalationFactor]*2* IIf([OutsideNevadaShipmentKilometers] .[OriginID]<>84,[PollutionEffEscorts Rural],[PollutionEffEscortsNavy Rural]))	Calculates the Rural Escort Pollution Health Effects Rural Proposed Action = Rural Shipment Kilometers calculated in MT OutsideNevadaShipmentKilometers Setup OriginID 84 = Navy; If origin does not equal 84, use Escort Pollution Health Effects Unit Risk Factor (PollutionEffEscorts Rural), else use Navy Escort Pollution Health Effects Rural Unit Risk Factor (PollutionEffEscortsNavy Rural) PollutionEffEscorts Rural = Escort Pollution Health Effects Unit Risk Factor used in Rural for non-Navy shipments PollutionEffEscortsNavy Rural = Escort Pollution Health Effects Unit Risk Factor used in Rural for Navy shipments Multiply by 2 for return trip
Outside NV Incident Free Navy Separate	Escorts Proposed Action Pollution	Sum(IIf([Outside NV Incident Free].[OriginID]<>84,Nz([Escorts Pollution Rural Proposed Action],0)+Nz([Escorts Pollution Suburban Proposed Action],0)+Nz([Escorts Pollution Urban Proposed Action],0),0))	Calculates the Total Escort Pollution Health Effects for non-Navy shipments Sums the Rural, Suburban, and Urban Escort Pollution Health Effects for non-Navy shipments
Outside NV Incident Free Navy Separate	Navy Escorts Proposed Action Pollution	Sum(IIf([Outside NV Incident Free].[OriginID]=84,Nz([Escorts Pollution Rural Proposed Action],0)+Nz([Escorts Pollution Suburban Proposed Action],0)+Nz([Escorts Pollution Urban Proposed Action],0),0))	Calculates the Total Escort Pollution Health Effects for Navy shipments Sums the Rural, Suburban, and Urban Escort Pollution Health Effects for Navy shipments

Table B-8. Traffic Fatalities Calculation

Query Name	Query Field	Equation Used	Description
MT OutsideNevadaShipment Kilometers Setup	Rural Proposed Action	Nz([Proposed Action],0)*Nz([Rural Kilometers],0)	Calculates Rural Shipment Kilometers Proposed Action = Proposed action shipments Rural Kilometers = Rural Kilometers
Outside NV Incident Free	Fatalities Rural Proposed Action	Sum(Nz([Rural Proposed Action],0)*Nz([Rural Fatalities],0)*2)	Calculates Rural Traffic Fatalities Rural Proposed Action = Rural Shipment Kilometers calculated in MT OutsideNevadaShipmentKilometers Setup Rural Fatalities = State Rural Fatality rate Multiply by 2 for return trip
Outside NV Incident Free	Escort Fatalities Rural Proposed Action	Sum([Rural Proposed Action]*2 *IIf([OutsideNevadaShipmentKilometers].[OriginID]<>84,[FatalitiesEscorts Rural],[FatalitiesEscortsNavy Rural]))	Calculates Rural Escort Traffic Fatalities Rural Proposed Action = Rural Shipment Kilometers calculated in MT OutsideNevadaShipmentKilometers Setup Multiply by 2 for return trip OriginID 84 = Navy; If origin does not equal 84, use Escort Traffic Fatalities Unit Risk Factor (FatalitiesEscorts Rural), else use Navy Escort Traffic Fatalities Unit Risk Factor (FatalitiesEscortsNavy Rural)
Outside NV Incident Free Navy Separate	Proposed Action Traffic Fatalities	Sum(Nz([Fatalities Rural Proposed Action],0)+Nz([Fatalities Suburban Proposed Action],0)+Nz([Fatalities Urban Proposed Action],0)+Nz([Escort Fatalities Rural Proposed Action],0)+Nz([Escort Fatalities Suburban Proposed Action],0)+Nz([Escort Fatalities Urban Proposed Action],0))	Calculates the Total Traffic Fatalities Sums the Rural, Suburban, and Urban Traffic Fatalities and the Rural, Suburban, and Urban Escort Traffic Fatalities

Table B-9. Groundshine Calculation (1 of 2)

Query Name	Query Field	Equation Used	Description
MT OutsideNevadaShipmentKilometers Setup	Rural Proposed Action	Nz([Proposed Action],0)*Nz([Rural Kilometers],0)	Calculates Rural Shipment KilometersProposed Action = Proposed action shipmentsRural Kilometers = Rural Kilometers
Outside NV Accidents	Proposed Action Rural Accidents	Nz([Rural Proposed Action],0)*Nz([Rural Accidents],0)*IIf([Outside NV Shipment Kilometers].[Mode]="Rail",4.2,1)	Calculates Rural AccidentsRural Proposed Action = Rural Shipment Kilometers calculated in MT OutsideNevadaShipmentKilometers SetupRural Accidents = State Accident RateIf the mode is rail multiply by 4.2, else multiply by 1
Outside NV Accident Severities	Proposed Action Rural Accidents 1	[Proposed Action Rural Accidents]*[Severity Category1]	Calculates Severity Category 1 AccidentsProposed Action Rural Accidents = Proposed Action Rural Accidents calculated in Outside NV AccidentsSeverity Category1 = Probability of Severity Category 1 Accident
Release Fraction Seventies	14 Year Release Fraction Severity1	[Ci/Cask 14]*[Severity Category1]	Calculates Release Fraction Severity 1Ci/Cask 14 = Curies per Cask after 14 years of storageSeverity Category1 = Release Fraction Category 1 for a Group and Fuel Type
Outside NV Release Risk	14 Year Proposed Action Rural Release Risk 1	[Proposed Action Rural Accidents 1]*[14 Year Release Fraction Severity1]	Calculates 14 Year Rural Release Risk 1Proposed Action Rural Accidents1 = Proposed Action Rural Accidents of Severity 1 calculated in Outside NV Accident Severities14 Year Release Fraction Severity1 = Release Fractions of Severity 1 calculated in Release Fraction Severities
Outside NV Release Risk	14 Year Proposed Action Rural Release Risk	Nz([14 Year Proposed Action Rural Release Risk 1],0)+Nz([14 Year Proposed Action Rural Release Risk 2],0)+Nz([14 Year Proposed Action Rural Release Risk 3],0)+Nz([14 Year Proposed Action Rural Release Risk 4],0)+Nz([14 Year Proposed Action Rural Release Risk 5],0)+Nz([14 Year Proposed Action Rural Release Risk 6],0)	Calculates Total Rural Release RiskSums Severity 1 through 6 Rural Release Risks

Table B-9. Groundshine Calculation (2 of 2)

Query Name	Query Field	Equation Used	Description
Outside NV Accident Risk	14 Year Proposed Action Rural GroundShine Risk	[14 Year Proposed Action Rural Release Risk]*[Rural Density] *[PopEscalationFactor]*[GroundShine]	Calculates Rural Groundshine Risk by Isotope and Population Zone14 Year Proposed Action Rural Release Risk = 14 Year Proposed Action Rural Release Risk calculated in Outside NV Release RiskRural Density = State Rural DensityPopEscalationFactor = State Population Escalation FactorGroundShine = GroundShine Dose Conversion Factor
Outside NV Accident Risk	14 Year Proposed Action GroundShine Risk	Nz([14 Year Proposed Action Rural GroundShine Risk],0)+Nz([14 Year Proposed Action Suburban GroundShine Risk],0)+Nz([14 Year Proposed Action Urban GroundShine Risk],0)	Calculates Groundshine Risk by IsotopeSums Rural, Suburban, and Urban Groundshine Risk
Outside NV Accident Risk Totals	14 Year Proposed Action GroundShine Risk	Sum(14 Year Proposed Action GroundShine Risk)	Calculates Total Groundshine RiskSums the 14 Year Proposed Action GroundShine Risk calculated in Outside NV Accident Risk

Table B-10. Ingestion Calculation

Query Name	Query Field	Equation Used	Description
MT OutsideNevadaShipmentKilometers Setup	Rural Proposed Action	Nz([Proposed Action],0)*Nz([Rural Kilometers],0)	Calculates Rural Shipment Kilometers Proposed Action = Proposed action shipments Rural Kilometers = Rural Kilometers
Outside NV Accidents	Proposed Action Rural Accidents	Nz([Rural Proposed Action],0)*Nz([Rural Accidents],0)*IIf([Outside NV Shipment Kilometers].[Mode]="Rail",4.2,1)	Calculates Rural Accidents Rural Proposed Action = Rural Shipment Kilometers calculated in MT OutsideNevadaShipmentKilometers Setup Rural Accidents = State Accident Rate If the mode is rail multiply by 4.2, else multiply by 1
Outside NV Accident Severities	Proposed Action Rural Accidents 1	[Proposed Action Rural Accidents]*[Severity Category1]	Calculates Severity Category 1 Accidents Proposed Action Rural Accidents = Proposed Action Rural Accidents calculated in Outside NV Accidents Severity Category1 = Probability of Severity Category 1 Accident
Release Fraction Severties	14 Year Release Fraction Severity1	[Ci/Cask 14]*[Severity Category1]	Calculates Release Fraction Severity 1 Ci/Cask 14 = Curies per Cask after 14 years of storage Severity Category1 = Release Fraction Category 1 for a Group and Fuel Type
Outside NV Release Risk	14 Year Proposed Action Rural Release Risk 1	[Proposed Action Rural Accidents 1]*[14 Year Release Fraction Severity1]	Calculates 14 Year Rural Release Risk 1 Proposed Action Rural Accidents1 = Proposed Action Rural Accidents of Severity 1 calculated in Outside NV Accident Severities 14 Year Release Fraction Severity1 = Release Fractions of Severity 1 calculated in Release Fraction Severities
Outside NV Release Risk	14 Year Proposed Action Rural Release Risk	Nz([14 Year Proposed Action Rural Release Risk 1],0)+Nz([14 Year Proposed Action Rural Release Risk 2],0)+Nz([14 Year Proposed Action Rural Release Risk 3],0)+Nz([14 Year Proposed Action Rural Release Risk 4],0)+Nz([14 Year Proposed Action Rural Release Risk 5],0)+Nz([14 Year Proposed Action Rural Release Risk 6],0)	Calculates Total Rural Release Risk Sums Severity 1 through 6 Rural Release Risks
Outside NV Accident Risk	14 Year Proposed Action Ingestion Risk	[14 Year Proposed Action Rural Release Risk]*[Food Transfer Factor]*[Ingestion]	Calculates Ingestion Risk by Isotope for Rural Population Zone 14 Year Proposed Action Rural Release Risk = 14 Year Proposed Action Rural Release Risk calculated in Outside NV Release Risk Food Transfer Factor = State specific Food Transfer Factor Ingestion = Ingestion Dose Conversion Factor
Outside NV Accident Risk Totals	14 Year Proposed Action Rural Ingestion Risk	Sum(14 Year Proposed Action Rural Ingestion Risk)	Calculates Total Ingestion Risk Sums the 14 Year Proposed Action Ingestion Risk calculated in Outside NV Accident Risk

Table B-11. Inhalation Calculation

Query Name	Query Field	Equation Used	Description
MT OutsideNevada ShipmentKilometers Setup	Rural Proposed Action	Nz([Proposed Action],0)*Nz([Rural Kilometers],0)	Calculates Rural Shipment Kilometers Proposed Action = Proposed action shipments Rural Kilometers = Rural Kilometers
Outside NV Accidents	Proposed Action Rural Accidents	Nz([Rural Proposed Action],0)*Nz([Rural Accidents],0)*IIf([Outside NV Shipment Kilometers].[Mode]="Rail",4.2,1)	Calculates Rural Accidents Rural Proposed Action = Rural Shipment Kilometers calculated in MT OutsideNevadaShipmentKilometers Setup Rural Accidents = State Accident Rate If the mode is rail multiply by 4.2, else multiply by 1
Outside NV Accident Severities	Proposed Action Rural Accidents 1	[Proposed Action Rural Accidents]*[Severity Category1]	Calculates Severity Category 1 Accidents Proposed Action Rural Accidents = Proposed Action Rural Accidents calculated in Outside NV Accidents Severity Category1 = Probability of Severity Category 1 Accident
Release Fraction Severties	14 Year Release Fraction Severity1	[Ci/Cask 14]*[Severity Category1]	Calculates Release Fraction Severity 1 Ci/Cask 14 = Curies per Cask after 14 years of storage Severity Category1 = Release Fraction Category 1 for a Group and Fuel Type
Outside NV Release Risk	14 Year Proposed Action Rural Release Risk 1	[Proposed Action Rural Accidents 1]*[14 Year Release Fraction Severity1]	Calculates 14 Year Rural Release Risk 1 Proposed Action Rural Accidents1 = Proposed Action Rural Accidents of Severity 1 calculated in Outside NV Accident Severities 14 Year Release Fraction Severity1 = Release Fractions of Severity 1 calculated in Release Fraction Severities
Outside NV Release Risk	14 Year Proposed Action Rural Release Risk	Nz([14 Year Proposed Action Rural Release Risk 1],0)+Nz([14 Year Proposed Action Rural Release Risk 2],0)+Nz([14 Year Proposed Action Rural Release Risk 3],0)+Nz([14 Year Proposed Action Rural Release Risk 4],0)+Nz([14 Year Proposed Action Rural Release Risk 5],0)+Nz([14 Year Proposed Action Rural Release Risk 6],0)	Calculates Total Rural Release Risk Sums Severity 1 through 6 Rural Release Risks
Outside NV Accident Risk	14 Year Proposed Action Rural Inhalation Risk	[14 Year Proposed Action Rural Release Risk]*[Respirable Fraction]*[Rural Density]*[PopEscalationFactor]*[Inhalation]	Calculates Inhalation Risk by Isotope and Population Zone 14 Year Proposed Action Rural Release Risk = 14 Year Rural Release Risk calculated in Outside NV Release Risk Respirable Fraction = Respirable Fraction of Group Rural Density = Rural Population Density PopEscalationFactor = State Population Escalation Factor Inhalation = Inhalation Dose Conversion Factor
Outside NV Accident Risk	14 Year Proposed Action Inhalation Risk	Nz([14 Year Proposed Action Rural Inhalation Risk],0)+Nz([14 Year Proposed Action Suburban Inhalation Risk],0)+Nz([14 Year Proposed Action Urban Inhalation Risk],0)	Calculates Inhalation Risk by Isotope Sums Rural, Suburban, and Urban Inhalation Risk
Outside NV Accident Risk Totals	14 Year Proposed Action Rural Inhalation Risk	Sum(14 Year Proposed Action Rural Inhalation Risk)	Calculates Total Inhalation Risk Sums the 14 Year Proposed Action Inhalation Risk calculated in Outside NV Accident Risk

Table B-12. Immersion Calculation (1 of 2)

Query Name	Query Field	Equation Used	Description
MT OutsideNevadaShipment Kilometers Setup	Rural Proposed Action	Nz([Proposed Action],0)*Nz([Rural Kilometers],0)	Calculates Rural Shipment Kilometers Proposed Action = Proposed action shipments Rural Kilometers = Rural Kilometers
Outside NV Accidents	Proposed Action Rural Accidents	Nz([Rural Proposed Action],0)*Nz([Rural Accidents],0)*IIf([Outside NV Shipment Kilometers].[Mode]="Rail",4.2,1)	Calculates Rural Accidents Rural Proposed Action = Rural Shipment Kilometers calculated in MT OutsideNevadaShipmentKilometers Setup Rural Accidents = State Accident Rate If the mode is rail multiply by 4.2, else multiply by 1
Outside NV Accident Severities	Proposed Action Rural Accidents 1	[Proposed Action Rural Accidents]*[Severity Category1]	Calculates Severity Category 1 Accidents Proposed Action Rural Accidents = Proposed Action Rural Accidents calculated in Outside NV Accidents Severity Category1 = Probability of Severity Category 1 Accident
Release Fraction Severties	14 Year Release Fraction Severity1	[Ci/Cask 14]*[Severity Category1]	Calculates Release Fraction Severity 1 Ci/Cask 14 = Curies per Cask after 14 years of storage Severity Category1 = Release Fraction Category 1 for a Group and Fuel Type
Outside NV Release Risk	14 Year Proposed Action Rural Release Risk 1	[Proposed Action Rural Accidents 1]*[14 Year Release Fraction Severity1]	Calculates 14 Year Rural Release Risk 1 Proposed Action Rural Accidents1 = Proposed Action Rural Accidents of Severity 1 calculated in Outside NV Accident Severities 14 Year Release Fraction Severity1 = Release Fractions of Severity 1 calculated in Release Fraction Severities

Table B-12. Immersion Calculation (2 of 2)

Outside NV Release Risk	14 Year Proposed Action Rural Release Risk	Nz([14 Year Proposed Action Rural Release Risk 1],0)+Nz([14 Year Proposed Action Rural Release Risk 2],0)+Nz([14 Year Proposed Action Rural Release Risk 3],0)+Nz([14 Year Proposed Action Rural Release Risk 4],0)+Nz([14 Year Proposed Action Rural Release Risk 5],0)+Nz([14 Year Proposed Action Rural Release Risk 6],0)	Calculates Total Rural Release Risk Sums Severity 1 through 6 Rural Release Risks
Outside NV Accident Risk	14 Year Proposed Action Rural Immersion Risk	[14 Year Proposed Action Rural Release Risk]*[Rural Density] *[PopEscalationFactor]*[Immersion]	Calculates Rural Immersion Risk by Isotope and Population Zone 14 Year Proposed Action Rural Release Risk = 14 Year Proposed Action Rural Release Risk calculated in Outside NV Release Risk Rural Density = State Rural Density PopEscalationFactor = State Population Escalation Factor Immersion = Immersion Dose Conversion Factor
Outside NV Accident Risk	14 Year Proposed Action Immersion Risk	Nz([14 Year Proposed Action Rural Immersion Risk],0)+Nz([14 Year Proposed Action Suburban Immersion Risk],0)+Nz([14 Year Proposed Action Urban Immersion Risk],0)	Calculates Immersion Risk by Isotope Sums Rural, Suburban, and Urban Immersion Risk
Outside NV Accident Risk Totals	14 Year Proposed Action Rural Immersion Risk	Sum(14 Year Proposed Action Rural Immersion Risk)	Calculates Total Immersion Risk Sums the 14 Year Proposed Action Immersion Risk calculated in Outside NV Accident Risk

Table B-13. Resuspension Calculation (1 of 2)

Query Name	Query Field	Equation Used	Description
MT OutsideNevadaShipmentKilometers Setup	Rural Proposed Action	Nz([Proposed Action],0)*Nz([Rural Kilometers],0)	Calculates Rural Shipment Kilometers Proposed Action = Proposed action shipments Rural Kilometers = Rural Kilometers
Outside NV Accidents	Proposed Action Rural Accidents	Nz([Rural Proposed Action],0)*Nz([Rural Accidents],0)*IIf([Outside NV Shipment Kilometers].[Mode]="Rail",4.2,1)	Calculates Rural Accidents Rural Proposed Action = Rural Shipment Kilometers calculated in MT OutsideNevadaShipmentKilometers Setup Rural Accidents = State Accident Rate If the mode is rail multiply by 4.2, else multiply by 1
Outside NV Accident Severities	Proposed Action Rural Accidents 1	[Proposed Action Rural Accidents]*[Severity Category1]	Calculates Severity Category 1 Accidents Proposed Action Rural Accidents = Proposed Action Rural Accidents calculated in Outside NV Accidents Severity Category1 = Probability of Severity Category 1 Accident
Release Fraction Severties	14 Year Release Fraction Severity1	[Ci/Cask 14]*[Severity Category1]	Calculates Release Fraction Severity 1 Ci/Cask 14 = Curies per Cask after 14 years of storage Severity Category1 = Release Fraction Category 1 for a Group and Fuel Type
Outside NV Release Risk	14 Year Proposed Action Rural Release Risk 1	[Proposed Action Rural Accidents 1]*[14 Year Release Fraction Severity1]	Calculates 14 Year Rural Release Risk 1 Proposed Action Rural Accidents1 = Proposed Action Rural Accidents of Severity 1 calculated in Outside NV Accident Severities 14 Year Release Fraction Severity1 = Release Fractions of Severity 1 calculated in Release Fraction Severities
Outside NV Release Risk	14 Year Proposed Action Rural Release Risk	Nz([14 Year Proposed Action Rural Release Risk 1],0)+Nz([14 Year Proposed Action Rural Release Risk 2],0)+Nz([14 Year Proposed Action Rural Release Risk 3],0)+Nz([14 Year Proposed Action Rural Release Risk 4],0)+Nz([14 Year Proposed Action Rural Release Risk 5],0)+Nz([14 Year Proposed Action Rural Release Risk 6],0)	Calculates Total Rural Release Risk Sums Severity 1 through 6 Rural Release Risks

Table B-13. Resuspension Calculation (2 of 2)

Query Name	Query Field	Equation Used	Description
Outside NV Accident Risk	14 Year Proposed Action Rural Resuspension Risk	[14 Year Proposed Action Rural Release Risk]*[Rural Density] *[PopEscalationFactor]*[Resuspension]	Calculates Rural Resuspension Risk 14 Year Proposed Action Rural Release Risk = 14 Year Rural Release Risk calculated in Outside NV Release Risk Rural Density = Rural Population Density PopEscalationFactor = State Population Escalation Factor Resuspension = Resuspension Dose Conversion Factor
Outside NV Accident Risk	14 Year Proposed Action Resuspension Risk	Nz([14 Year Proposed Action Rural Resuspension Risk],0)+Nz([14 Year Proposed Action Suburban Resuspension Risk],0)+Nz([14 Year Proposed Action Urban Resuspension Risk],0)	Calculates Resuspension Risk by Isotope Sums Rural, Suburban, and Urban Resuspension Risk
Outside NV Accident Risk Totals	14 Year Proposed Action Resuspension Risk	Sum(14 Year Proposed Action Resuspension Risk)	Calculates Total Resuspension Risk Sums the 14 Year Proposed Action Resuspension Risk calculated in Outside NV Accident Risk

Table B-14. Loss of Shielding Calculation

Query Name	Query Field	Equation Used	Description
MT OutsideNevadaShipment Kilometers Setup	Rural Proposed Action	Nz([Proposed Action],0)*Nz([Rural Kilometers],0)	Calculates Rural Shipment Kilometers Proposed Action = Proposed action shipments Rural Kilometers = Rural Kilometers
Outside NV Accidents	Proposed Action Rural Accidents	Nz([Rural Proposed Action],0)*Nz([Rural Accidents],0)*IIf([Outside NV Shipment Kilometers].[Mode]="Rail",4.2,1)	Calculates Rural Accidents Rural Proposed Action = Rural Shipment Kilometers calculated in MT OutsideNevadaShipmentKilometers Setup Rural Accidents = State Accident Rate If the mode is rail multiply by 4.2, else multiply by 1
Outside NV Accident Severities	Proposed Action Rural LOS 1	[Proposed Action Rural Accidents]*[LOS Severity Category1]*[LOS Severity Category1 Exposure]	Calculates Severity Category 1 Loss of Shielding Proposed Action Rural Accidents = Proposed Action Rural Accidents calculated in Outside NV Accidents LOS Severity Category1 = Probability of Severity Category 1 Loss of Shielding LOS Severity Category1 Exposure = Exposure to individuals in Severity Category 1 Loss of Shielding accident
Outside NV LOS Risk	Proposed Action Rural LOS Risk	Sum((Nz([Proposed Action Rural LOS 1],0)+Nz([Proposed Action Rural LOS 2],0)+Nz([Proposed Action Rural LOS 3],0)+Nz([Proposed Action Rural LOS 4],0)+Nz([Proposed Action Rural LOS 5],0)+Nz([Proposed Action Rural LOS 6],0))*[Rural Density]*[PopEscalationFactor])	Sums Severity 1 through 6 Rural Loss of Shielding Risks Rural Density = Rural Population Density PopEscalationFactor = State Population Escalation Factor
Outside NV LOS Risk	Proposed Action LOS Risk	Nz([Proposed Action Rural LOS Risk],0)+Nz([Proposed Action Suburban LOS Risk],0)+Nz([Proposed Action Urban LOS Risk],0)	Sums Rural, Suburban, and Urban Loss of Shielding Risk

APPENDIX C. SPECIAL FUNCTIONS

The special functions described in this appendix are used to find and return data. Comments in the functions are denoted by an apostrophe.

Get_NevadaToEndNode

This function is used to find and return the accident risk or incident-free dose consequences of the rail segments in Nevada prior to the end nodes. These segment doses are added to the regional corridor accident risk or incident-free doses to determine the total accident risk or incident-free dose consequences in Nevada.

Public Function Get_NevadaToEndNode (strCorridor As String, iCaseID As Integer, strFieldName As String) As Double

Dim i As Integer

```
With rsData
  Select Case strCorridor

  Case "Apex/Valley Modified Rail"
    .FindFirst "[Corridor] = " & Chr(34) & "Nevada to APEX" & Chr(34) & " And CaseID = " & iCaseID
  Case "Apex/Dry Lake HH Truck"
    .FindFirst "[Corridor] = " & Chr(34) & "Nevada to DRY LAKE" & Chr(34) & " And CaseID = " & iCaseID
  Case "Beowawe/Carlin Rail"
    .FindFirst "[Corridor] = " & Chr(34) & "Nevada to BEOWAWE" & Chr(34) & " And CaseID = " & iCaseID
  Case "Caliente HH Truck"
    .FindFirst "[Corridor] = " & Chr(34) & "Nevada to CALIENTE" & Chr(34) & " And CaseID = " & iCaseID
  Case "Caliente HH Truck Chalk Mountain"
    .FindFirst "[Corridor] = " & Chr(34) & "Nevada to CALIENTE" & Chr(34) & " And CaseID = " & iCaseID
  Case "Caliente HH Truck Las Vegas"
    .FindFirst "[Corridor] = " & Chr(34) & "Nevada to CALIENTE" & Chr(34) & " And CaseID = " & iCaseID
  Case "Caliente Rail"
    .FindFirst "[Corridor] = " & Chr(34) & "Nevada to ECCLES" & Chr(34) & " And CaseID = " & iCaseID
  Case "Caliente/Chalk Mountain Rail"
    .FindFirst "[Corridor] = " & Chr(34) & "Nevada to ECCLES" & Chr(34) & " And CaseID = " & iCaseID
  Case "Jean Rail"
    .FindFirst "[Corridor] = " & Chr(34) & "Nevada to JEAN" & Chr(34) & " And CaseID = " & iCaseID
  Case "Jean/Sloan HH Truck"
    .FindFirst "[Corridor] = " & Chr(34) & "Nevada to JEAN" & Chr(34) & " And CaseID = " & iCaseID
  Case "Nevada to REPOSITORY"
    Get_NevadaToEndNode = 0
    Exit Function
  End Select
  If Not .NoMatch Then
    For i = 0 To .Fields.Count - 1
      If .Fields(i).Name = strFieldName Then
        Get_NevadaToEndNode = .Fields(i)
        Exit For
      End If
    Next
```

```
      End If
    End With
End Function
```

Get_NationalToEndNode

This function is used to find and return the accident risk or incident-free doses of all segments outside Nevada. These segment doses are added to the Nevada accident risk or incident-free doses to determine the total national accident risk or incident-free dose consequence.

Public Function Get_NationalToNevada(strCorridor As String, iCaseID As Integer, strFieldName As String) As Double

```
Dim i As Integer

  With rsData
    Select Case strCorridor
    Case "Apex/Valley Modified Rail"
      .FindFirst "[Node Name] = " & Chr(34) & "APEX" & Chr(34) & " And CaseID = " & iCaseID
    Case "Apex/Dry Lake HH Truck"
      .FindFirst "[Node Name] = " & Chr(34) & "DRY LAKE" & Chr(34) & " And CaseID = " & iCaseID
    Case "Beowawe/Carlin Rail"
      .FindFirst "[Node Name] = " & Chr(34) & "BEOWAWE" & Chr(34) & " And CaseID = " & iCaseID
    Case "Caliente HH Truck"
      .FindFirst "[Node Name] = " & Chr(34) & "CALIENTE" & Chr(34) & " And CaseID = " & iCaseID
    Case "Caliente HH Truck Chalk Mountain"
      .FindFirst "[Node Name] = " & Chr(34) & "CALIENTE" & Chr(34) & " And CaseID = " & iCaseID
    Case "Caliente HH Truck Las Vegas"
      .FindFirst "[Node Name] = " & Chr(34) & "CALIENTE" & Chr(34) & " And CaseID = " & iCaseID
    Case "Caliente Rail"
      .FindFirst "[Node Name] = " & Chr(34) & "ECCLES" & Chr(34) & " And CaseID = " & iCaseID
    Case "Caliente/Chalk Mountain Rail"
      .FindFirst "[Node Name] = " & Chr(34) & "ECCLES" & Chr(34) & " And CaseID = " & iCaseID
    Case "Jean Rail"
      .FindFirst "[Node Name] = " & Chr(34) & "JEAN" & Chr(34) & " And CaseID = " & iCaseID
    Case "Jean/Sloan HH Truck"
      .FindFirst "[Node Name] = " & Chr(34) & "JEAN" & Chr(34) & " And CaseID = " & iCaseID
    Case "Nevada to REPOSITORY"
      .FindFirst "[Node Name] = " & Chr(34) & "REPOSITORY" & Chr(34) & " And CaseID = " & iCaseID
    End Select
    If Not .NoMatch Then
      For i = 0 To .Fields.Count - 1
        If .Fields(i).Name = strFieldName Then
          Get_NationalToNevada = .Fields(i)
          Exit For
        End If
      Next
    End If
  End With
End Function
```

APPENDIX D. RADTRAN CORRELATION

The offlink dose is calculated by RADTRAN using the following equations (Equation 24, DIRS 155430-Neuhauser et al. 2000)

$$D_{off,gamma} = 4Qk_0 * DR_V * \frac{PD_L}{V_L} * NSH_L * DIST_L * FG_V \left[\int_{min}^{sw} I_G(x)dx * RPD + \int_{sw}^{max} I_G(x)dx * SF \right]$$

$$D_{off,neutron} = 4Qk_0 * DR_V * \frac{PD_L}{V_L} * NSH_L * DIST_L * FN_V \left[\int_{min}^{sw} I_N(x)dx * RPD + \int_{sw}^{max} I_N(x)dx * SF \right]$$

where:

Q = a unit conversion factor

k_0 = a package shape factor

DR_V = the transport index (TI) in mrem/hr

PD_L = the population density ½ mile on either side of the route along the particular link

V_L = the speed of the vehicle along the particular link

NSH_L = the number of shipments traveling along the link

$DIST_L$ = the link length

FG_V and FN_V = the gamma and neutron fractions, respectively, of the TI

RPD = the ratio of pedestrian density to residential population density

SF = the shielding factor (no shielding is assumed in the EIS)

SW = sidewalk width

The two integrals express the dose rate at a distance r from a spherically symmetric source of radiation using an inverse square ($1/r^2$) relationship and including the absorption and buildup factors.

The database substitutes tables of population densities, numbers of shipments along various routes, and lengths of various route segments for the variables PD_L, NSH_L, and $DIST_L$. With these variables set equal to one in the RADTRAN input, RADTRAN is then used to calculate unit risk factors for rural, suburban, and urban segments of the various routes for each of the modes used (legal-weight truck, heavy-haul truck, rail, and barge). The resulting table of unit risk factors can then be multiplied by the shipment kilometers to yield offlink incident-free doses for each segment of each route. The doses can then be combined as desired. Doses to occupants of vehicles sharing the transportation route with the radioactive cargo (onlink dose) are calculated in an analogous way using Equations 31-34 of Neuhauser et al. (DIRS 155430-2000). Doses at stops are also expressed as unit risk factors per kilometer of route length. In this case, the stop dose is calculated using Equations 37 and 38 or 39-41 of Neuhauser et al. (DIRS 155430-2000), and then divided by the average distance between stops to yield a per-kilometer unit risk factor.

Accident dose risks were determined, as illustrated, by the calculation of inhalation dose using Equations 76 and 94 of Neuhauser et al. (DIRS 155430-2000).

$$D_{inh} = Q*AR_L \sum_m \sum_i \sum_j \sum_o \gamma_{j,L}\, Ci_i*RF_{i,j}*AER_{i,j}*RESP_{i,j}*RPC_{i,o}*IF*BR*PD_L*A_n$$

where:

Q	= a unit conversion factor
$\sum_m$	= the sum over all physical/chemical groups (gases, volatiles, etc.)
$\sum_i$	= the sum over all isotopes in each physical/chemical group
$\sum_j$	= the sum over all conditional probabilities of accidents of a particular severity ("severity fractions")
$\sum_o$	= the sum over all affected organs
$\gamma_{j,L}$	= the probability of an accident of severity j on route segment L
Ci_i	= the number of curies of the ith isotope
$RF_{i,j}$	= the fraction of each isotope i released in an accident of conditional probability (severity) j
AR_L	= the accident rate along the route segment
$AER_{i,j}$	= the fraction of released isotope i aerosolized; this is set = 1 in the EIS
$RESP_{i,j}$	= the fraction of aerosolized isotope i that is respirable (< 10 microns diameter); this is set = 1 in the EIS
RPC_i	= the dose rate conversion factor (rem/Ci inhaled) for isotope i and organ o (from Federal Guidance Report No. 11, DIRS 101069-Eckerman, Wolbarst, and Richardson 1988, all)
IF	= the dilution factor due to atmospheric dispersion
BR	= the average breathing rate
PD_L	= as before, the population density along the route segment
A_n	= the total area of the dispersed plume "footprint"; this incorporates the Pasquill-Gifford meteorological constants

An accident unit risk factor, for inhalation in this case, is then calculated by RADTRAN for one curie of each isotope, using the parameters:

$$\Sigma_O\ AER_{i,j}*RESP_{i,j}*RPC_{i,o}*IF*BR*A_n.$$

The dispersion is calculated for national average meteorology and is included in the unit risk factor. Analogous unit risk factors are calculated for 1 curie of each isotope for groundshine, cloudshine (immersion), and resuspension dose risks. These unit risk factors are tabulated in a lookup table in the database.

The database contains tables for the following parameters: AR_L, $\gamma_{j,L}$, Ci_i, $(RF_{i,j}*AER_{i,j}*RESP_{i,j})$, and PD_L for all route segments, cask types, transportation modes, and spent nuclear fuel and high-level waste inventories. Accident dose risks can then be calculated for any route segment, any particular spent fuel or waste, and any particular transportation mode and container, by applying the relational design and multiplying the unit risk factors by the appropriate fields in those tables.

Appendix B
Excel Files for Severe Accident Release Fraction Modeling by Fuel Type

Table B-1 lists the DOE fuel categories and their applicable release fraction spreadsheet files. The last letter in the spreadsheet file name, R or T, designates shipment by rail or truck, respectively. This transport mode identified may be followed by a revision number.

Table B-1. DOE Spent Nuclear Fuels

DOE Fuel Category		Applicable Release Fractions
No.	**Description**	
1	Metallic spent fuel	RF_UMETAL_R RF_UMETAL_T
2	Uranium-zirconium	RF_UMETAL_R RF_UMETAL_T
3	Uranium-molybdenum	RF_UMETAL_R RF_UMETAL_T
4	Uranium oxide intact	RF_PWR_R RF_PWR_T
5	Uranium oxide failed/declad/aluminum clad fuel	RF_FAILOX_R RF_FAILOX_T
6	Uranium aluminum fuel	RF_AL_R RF_AL_T
7	Uranium silicide fuel	RF_AL_R RF_AL_T
8	Thorium/uranium carbide high integrity fuel	RF_HTGR-H_R RF_HTGR-H_T
9	Thorium/uranium carbide low integrity fuel	RF_HTGR-L_R RF_HTGR-L_T
10	Plutonium/uranium carbide, non-graphite	RF_UPuC_R RF_UPuC_T
11	Mixed oxide	RF_PWR_R RF_PWR_T
12	Uranium thorium oxide	RF_PWR_R RF_PWR_T
13	Uranium zirconium hydride	RF_UZrH_R RF_UZrH_T
14	Sodium-bonded uranium and uranium-plutonium metal alloy fuel	RF_UMETAL_R RF_UMETAL_T
15	Naval fuel	RF_Navy_R
16	Miscellaneous	RF_UMETAL_R RF_UMETAL_T

Table B-2 lists the vitrified high-level waste and shipments of boiling-water reactor (BWR) and pressurized-water reactor (PWR) fuels in depleted uranium casks.

Table B-2. High-level Radioactive Waste and Commercial Spent Fuel

Fuel Category Description	Applicable Release Fractions
Vitrified high-level waste	RF_HLW _R
	RF_HLW_T
PWR spent fuel in depleted uranium casks	RF_PWR_DU_T
BWR spent fuel in depleted uranium casks	RF_BWR_DU_T

Appendix C
Modification of DIRS 152476 (Sprung, et al, 2000) Release Model for Different Fuel Types

The first part of this appendix provides a brief description of the release fraction modeling of severe accidents developed in DIRS 152476 (Sprung, et al, 2000, Chapters 4 through 7). This will be followed by a description of some of the changes made to models of other fuel types that could be shipped to the proposed Yucca Mountain repository.

The DIRS 152476 (Sprung, et al, 2000, Chapter 7) model, developed to estimate the fraction of radioactive materials released under a variety of transportation accident environments, contains four basic parts that have been integrated into an assessment model. The first element of the model is the structural response of the cask/fuel rod system when a variety of severe impact and thermal loads are imposed. The response is expressed as a cask breach area and the fraction of the fuel rods failed. The second part of the model estimates the fractions of the fuel materials that are released to the internals of the cask. The model has two components, the quantity of material available for release in the vicinity of the breach and the fraction released from the blowdown of the pressurized fuel rod. The third part of the model looks at the "plating out" of the released materials onto the internal surfaces of the cask. The fourth and final part of the model looks at the release of the material still airborne in the cask through the cask breach.

Several assumptions are embedded in the DIRS 152476 (Sprung, et al, 2000 Chapter 7) PWR and BWR release fraction models that do not apply to some of the other fuel types being shipped. The fraction of material released when the internal pressure inside the cask is relieved by discharges through the breached cask is most affected. PWR fuel rods are pressurized, while other fuel types may not be pressurized. At 300°C, the internal pressure inside a spent PWR fuel rod is assumed to be about 30 atmospheres. If all of the fuel rods were to fail, the estimated pressure in the cask would be about 5 atmospheres. This reduction takes into consideration the ratio of the free volume in the cask to the plenum volume in the fuel rods. The 5-atmosphere pressure inside the spent fuel cask is assumed to be the same for the BWR fuel. The gas generation term must be removed to correctly model fuel that is either not pressurized or has no gas plenum.

The PWR and BWR models also assume that any fuel cladding not failed on impact would fail at 750°C, and this assumption may not apply to other fuel types. At 750°C, the cladding on PWR fuel would no longer resist the internal pressure inside the fuel rod. For those fuel types with no pressurized gas plenum, removal of the pressure generation term could solve this problem. Many fuel types are placed in canisters and, as shown in Appendix D, these canisters will only fail from impact. Thus, any releases from thermal heating are still limited to those canisters that failed on impact. The basic equation used in the PWR and BWR analysis is:

$$RF_T = fr_i * f_{RCi} * (1 - f_{di}) * f_{esi} + (1 - fr_i) * f_{RCt} * (1 - f_{dt}) * f_{et}$$

where:

- fr_i = the fraction of the clad failed on impact
- f_{RCi} = the fraction of the fuel component released on impact
- f_{di} = the fraction of the fuel component deposited on the inside surfaces of the cask
- f_{esi} = a series of expansion terms used to estimate the fraction of the material available for release that is actually released
- f_{RCt} = the fraction of the fuel component released from thermal heating
- f_{dt} = the fraction of the fuel component deposited on the inside surfaces of the cask during thermal heating
- f_{et} = the thermal expansion terms used to estimate the fraction of the material available for release that is actually released during the fire

The above equation shows that if the scenario includes a severe fire, any of the clad not failed by the initial impact is assumed to fail from heating. Failure assumptions are also embedded in the four expansion terms used to estimate the fraction of the released material not swept out of the cask in the various release scenarios. The general format for the expansion terms is:

$$f_{e1} = \left[\frac{p_f T_s}{p_s T_f}\right]$$

In the above equation, the subscript "s" refers to the starting temperature and pressure after clad failure but before any material is released from the cask. The subscript "f" refers to the final pressure and temperature; in the case of the pressure term, it is atmospheric pressure. The form of the expansion factor is easily derived from the ideal gas law as the following equation shows:

$$(V_f - V_s) = \left[1 - \frac{p_f T_s}{p_s T_f}\right] V_f = (1 - f_e) V_f$$

The expansion factor represents the fraction of the gas in the cask that is not removed at the time of release.

As an example of how the expansion factors are used in the model, consider the case in which 25 percent of the clad fails on impact and then the rest of the clad fails at 750°C. Also assume that if all of the clad fails and the temperature does not increase, the pressure inside the cask would be 5 atm. The equation for the pressure rise when not all of the clad fails is:

$$p_s = 1 + 4f$$

where f is the clad failure fraction. In the above case, at the time of impact, the cask pressure will increase to 2 atm and then decrease as the gas inside the cask escapes through the breach in the cask. At 750°C, the remaining clad fails; therefore, p_s is set to 4 to model the effect of the failure from thermal heating. In this second case, the f used in the equation is one minus the fraction of the clad failed in impact. This is the model that has to be adjusted to take into account the behavior of the spent fuels with no pressurized gas plenum.

In developing the release fractions for fuel types that would be shipped in canisters, the first change was to make both the impact and thermally driven releases proportional to the fraction of the canisters assumed to fail in a transport accident. The second change was to limit the thermally driven release term so only the fraction of the material not initially released upon impact is considered. This change was necessary because this conservation of mass term was previously handled by the $(1\text{-}f_{ri})$ term that was in the thermal release part of the equation. The overall release equation becomes:

$$RF_T = fr_i * f_{RCi} * (1 - f_{di}) * f_{esi} + fr_i * (1 - f_{RCi}) * f_{RCt} * (1 - f_{dt}) * f_{et}$$

In this expression, fr_i is the fraction of the canisters failed on impact instead of the fraction of fuel rods failed. This change removes any credit taken for the integrity of the fuel rod clad. In the PWR and BWR model, the "i" in f_{esi} represents three expansion factors that model the initial release and the subsequent releases as the fuel heats up in a fire. There is no "i" associated with the f_{et} term because all of the expansion can be covered in one term. Maintaining as much of the nomenclature used in DIRS 152476 (Sprung et al. 2000, Section 7.2), expansion factors 1 through 3 are modeled as expansion factors following impact and the expansion factor 4 is modeled as a thermally driven expansion factor. The first expansion factor is used to model the impact driven release. No change is required to this factor because impact initiated failures of the canister are being considered in the model. The second factor has no pressure expansion factor and is used to model the release of impact generated particulates and gases during the heating of the cask up to the point of clad failure, 750°C in the case of the PWR and BWR fuel. No change is required to this term as well. The third expansion factor term in the DIRS 152476 (Sprung et al. 2000, p. 7-24) model is the fraction of the impact driven release, not removed by the first two expansions, that is now released because of the thermal failure of the clad and the subsequent heating to 1,000°C. The fourth expansion term estimates the fraction of the material remaining in the cask following the thermally driven failure of the clad and the subsequent heating of the fuel up to 1,000 °C. Since there is no failure of the spent fuel canister until the temperature is well above 1,000°C, the pressure driven release part of both the third and fourth expansion terms must be removed. Thus, the expansion terms take on the form:

$$f_{ej} = \left[\frac{T_s}{T_f}\right]$$

Once the pressure terms are removed, f_{e3} becomes identical to f_{e4}. Rather than eliminating one of the terms, it was decided to use f_{e3} in the impact part of the equation and f_{e4} in the thermal release part of the model.

In the impact part of the calculation, various cases estimate the release at the time of impact at 750°C and at 1,000°C.

The fraction remaining in the cask after the impact driven release is f_{e1}. The fraction remaining at 750°C is $f_{e1}*f_{e2}$. Based on the new definition of f_{e3}, the fraction remaining in the cask at 1,000°C is $f_{e1}*f_{e2}*f_{e3}$. The correctness of this model is shown using the following equation:

$$F_i(1000) = \left[\frac{p_1 * 573}{p_i * 623}\right] * \left[\frac{623}{1023}\right] * \left[\frac{1023}{1273}\right] = f_{e1} * f_{e2} * f_{e3}$$

where:

F_i = the fraction remaining in the cask at 1,000°C,

p_i = the pressure in the cask after the canister fails on impact, and

p_1 = 1 (atmospheric pressure)

It follows logically that the fraction released when both the canister and cask breach is:

$$RF_i(623) = (1 - f_{e1})$$

For the case where the cask and canister fail followed by heating to 750°C, the additional fraction released during the heating from 350 to 750°C (1,023°K) is:

$$RF_i(1023) = f_{e1} * (1 - f_{e2})$$

Finally, for the case where the fire heats the fuel canister up to 1,000°C, the additional fraction released in the heating from 750 to 1,000°C is:

$$RF_i(1273) = f_{e1} * f_{e2} * (1 - f_{e3})$$

Lastly, the form of the thermal release fraction term is as follows:

$$RF_t(1273) = fr_i(1 - f_{RCi}) f_{RCt}(1 - f_{dt})(1 - f_{e4})$$

The main sections of the calculation package focus on the actual numbers used in the release fraction model for the various waste types. In each assessment, three areas are discussed: canister failure rates on impact, cask internal pressures as they relate to expansion factors, and fuel release fractions. Table C-1 shows a comparison of the PWR and canister models for Rail Case 9. In this case, the impact occurs between 97 to 145 kilometers per hour (60 to 90 miles per hour) and, in a subsequent fire, the material is heated to 1,000°C . It is assumed that all of the fuel is at 300°C during shipment. In the PWR case, if all fuel fails, the cask would be pressurized to 5 atmospheres at 300 °C. If all canisters fail and assuming no pressurized fuel is in the canister, the cask will be pressurized to 2.43 atmospheres at 300°C.

Table C-1. Summary of PWR and canister modeling differences case.

PWR Equation	PWR Value	Canister Equation	Canister Value
f_r	0.59	f_r	0.20
P	5.	P	2.45
p_a	1	p_a	1
T_a	573 °K	T_a	573 °K
T_s	623 °K	T_s	623 °K
T_b	1023 °K	T_b	1023 °K
T_f	1273 °K	T_f	1273 °K
$p_i = 1 + (P-1) * f_r$	3.36	$p_i = 1 + (P-1) * f_r$	1.29
$f_{e1} = T_a / (p_a T_s)$	0.274	$f_{e1} = T_a / (p_a T_s)$	0.713
$f_{e2} = T_s / T_b$	0.609	$f_{e2} = T_s / T_b$	0.609
$p_b = 1 + (P-1)(1-f_r)$	2.64	Canister does not fail on heating to 1000 °C	
$f_{e3} = T_a / (p_a T_b)$	0.167	$f_{e3} = T_b / T_f$	0.804
$f_{e4} = T_b / (p_b T_f)$	0.304	$f_{e4} = T_b / T_f$	0.804
$F_i = 1 - f_{e1} + f_{e1}(1-f_{e2}) + f_{e3}(1-f_{e4})$	0.949	$F_i = 1 - f_{e1} + f_{e1}(1-f_{e2}) + f_{e1} f_{e2}(1-f_{e3})$	0.651
$F_t = (1-f_{e4})$	0.696	$F_t = (1-f_{e4})$	0.196

The comparison between the PWR and canister equations shows the major differences in the modeling. There is no difference in the equations for f_{e1} and f_{e2}. The only difference is in the pressure inside the cask at the time of failure and the failure fractions of the fuel rods in the cases of the PWR cask and the canister in the revised model. The significant difference in equations occurs with f_{e3} and f_{e4} because there is no canister failure when the cask heats up beyond 750°C. Part of the change is to remove any pressure term from f_{e3} and f_{e4} from the canister model. However, there is another change as well. In the PWR model, f_{e3} is modeled as the fraction of the radioactive material that remains in the cask after the initial gas release from the failed fuel pins plus the additional gas released as the fuel heats up from 300°C to the burst temperature of the remaining rods, 750°C. It is then multiplied by $(1-f_{e4})$, which is the fraction of the remaining material present in the cask atmosphere that is pushed out of the cask when the rods fail at 750°C and the fuel subsequently heats up to 1,000°C, the final temperature for Case 9. The term F_i is the fraction of the material released from the fuel pin on impact that remains airborne in the cask and is subsequently released as part of the accident sequence. The equation shows three terms: the fraction released on impact, the fraction released during the heatup to 750°C, and the fraction released when the remaining fuel rods burst and the fuel heats up to 1,000°C. The same three phenomena are modeled for the canister. The product $f_{e1}f_{e2}$ is the amount of material made airborne in the cask that is still present at 750°C, and $(1-f_{e3})$ is the fraction of that remaining material that is pushed out of the cask as the cask heats up from 750°C to its final temperature of 1,000°C.

In the PWR model the thermal release is initiated at the time the fuel pins start to fail at 750°C and includes the effect of the additional gas generation as the fuel pins fail. In the case of the canister, there is only the thermal expansion effect as the gas heats up from 750°C to 1,000°C. The difference in the equations for f_{e4} in both models reflects this difference.

The DIRS 152476 (Sprung, et al, 2000, Chapter 7) model. Thus far, the analysis focused almost entirely on the fourth component, the displacement model that forces any radioactive material that is airborne in the cask out through the breach in the cask. The first parts of the model address the behavior of the fuel and its release from the cladding. In developing the models for the various fuel types, canistered and uncanistered, these release fractions will be adjusted to reflect the characteristics of the material being transported. The third part of the model, the fraction of the material released from the fuel rod that is deposited on the inner surfaces of the cask, is assumed to be determined by the cask design and not the fuel material being shipped. This of course is an approximation, but it seems reasonable given that the size of the opening, and therefore the length of time available for deposition on the inner surfaces, is a function of the design and its response to the severe transportation accident environment.

Expansion factors for TRIGA fuel

The behavior of TRIGA fuel on heating is unique. TRIGA fuel is made up of approximately 8 percent uranium and 92 percent zirconium hydride ($ZrH_{1.88}$). The disassociation of the hydride shuts down a TRIGA reactor when it is operating in the pulse mode. At about 250°C, any hydrogen that is reacted with the uranium to form a uranium hydride will be given off as gas. As the temperature is increased, zirconium hydride continues to dissociate. Based on experimental data (DIRS 103756-DOE-1994, P. 4-73), the overpressure of hydrogen at equilibrium with zirconium hydride is about 0.5 atmosphere at 700°C and about 1 atmosphere at about 900°C. Thus, in a fire at 1,000°C, if the canister and the TRIGA fuel pins are breached, the hydrogen gas would evolve, and the volatile cesium and noble gases would be swept from the cask with the hydrogen.

Until the hydrogen gas starts to evolve, the behavior of the gas in the canister containing the TRIGA fuel will not differ from the behavior of any other unpressurized fuel in a canister. Hydrogen generation may be modeled by assuming that all of the hydrogen builds up in the cask and releases using the gas expansion models. The hydrogen gas would tend to sweep material from the cask. Assuming the cask works more like a homogeneous, stirred reactor, the release fraction equation becomes:

$$f_{e3} = e^{-G/V}$$

where G/V is the volume of gas generated divided by the cask volume. When this ratio is greater than 7, less than 0.1 percent of the material released from the fuel pin and not released from previous gas expansions remains in the cask. A value of "0" for an expansion factor means that all of the material is released, and "1" means it is all retained. Thus, a value of zero for f_{e3} is equivalent to releasing all material still airborne in the cask. Since the thermal model assumes deposited cesium would be volatilized and available for release in the cases where the fuel reaches 1,000°C, using the stirred tank model is equivalent to releasing all of the cesium that was previously deposited on the internal surfaces of the cask following an impact sufficient to fail both the fuel clad on the TRIGA fuel and the canister.

The uranium zirconium hydride fuel is assumed to be a powder following the numerous hydride/dehydride cycles it has undergone during its time in the reactor. The release fraction resulting from the failure of a fuel rod containing a powder would be 0.003 [DIRS 103756-1994, pp. 4-73]. Because there is no volatilization at temperatures less than 750°C, this release fraction would be used for particulates, cesium, and ruthenium. The crud release fraction and the noble gas release fractions would be the same as those used for the PWR and BWR fuels. Any cesium released as a result of the initial impact but not released from the cask on either cask or seal failure would be volatilized once the temperature in the cask exceeds 750°C.

Because the expansion factor was essentially zero for these cases, any revolatilized cesium would be released. The model was modified to eliminate the oxidation and subsequent enhanced release of ruthenium. Approximately 20 percent of the TRIGA fuel slated for disposal is clad in aluminum, with a melting point of 659.7°C. Liquid aluminum would scavenge any free oxygen in the cask, thereby preventing the formation of the volatile higher oxides of ruthenium. Even for the remaining 80 percent, of which most (87.5 percent) is stainless steel or inconel clad and the remainder (about 12.5 percent) is unclad, the powdered uranium and zirconium would be very effective oxygen-getters once the hydride had decomposed. The resulting highly reducing environment would effectively suppress ruthenium oxidation, thereby preventing a ruthenium release that is greater than the particulate release. Oxygen scavenging in the cask also prevents the reaction of hydrogen with oxygen. Hydrogen leaking from a breached cask would burn in an external fire but would simply dissipate in the absence of a fire.

Appendix D
Canister Failure Rates

Estimates of the fraction of the DOE spent fuel canisters that are likely to fail on impact in a severe transport accident are based on experimental data on simulated HLW canisters DIRS 102088 (Smith and Ross, 1975, all). In the tests, 2 of 12 canisters failed when they struck the wall at 72 kilometers (45 miles) per hour and 5 of 7 failed when they struck the wall at 129 kilometers (80 miles) per hour. The HLW analysis equated the 45-mile-per-hour impacts to the 48- to 97-kilometer (30- to 60-mile) per hour impact bin, and the 80-mile-per-hour impacts to the 97- to 145-kilometer (60- to 90-mile) per-hour impact bin, in DIRS 152476 (Sprung et al. 2000, Chapter 7). Thus, the failure rates for these two bins were taken as 0.20 and 0.70 based on the fraction of the canisters that failed at 45 and 80 miles per hour.

It is assumed that all canisters would fail at impact speeds greater than 90 miles per hour (the 90-to-120 miles per hour and the greater-then-120 miles per hour cases of Sprung et al (DIRS 152476-2000, page 7-76). Since the DOE spent fuel canister has a rounded (as opposed to a flat) bottom, more impact energy would be required for failure. Using general scaling laws, the impact stress increases linearly with velocity and decreases with the radius of curvature to the two-thirds power. The dish-like bottom has a radius of curvature that is about double the assumed equivalent 3/8-inch radius of the flat-bottomed HLW canister. Using these scaling laws, the 72-kilometer (45-mile) per-hour impact of the HLW canister will impart the same stress as a 113-kilometer (70-mile) per-hour impact on the spent fuel canister. Similarly, the 129-kilometer (80-mile) per-hour HLW canister impact will be equivalent to 206-kilometer (128-mile) per-hour impact on the spent fuel canister. When these points are plotted and the failure rates averaged over the DIRS 152476 (Sprung, et al, 2000, p.7-76) impact speed cases, failure would occur in 0.02, 0.20, 0.50, and 1.0 for the 30- to 60-mile, 60- to 90-mile, 90- to 120-mile, and greater than 120-mile per-hour impact speed cases, respectively.

Regarding the expansion factor estimation, the DOE spent fuel canister design document (DIRS 137713, DOE, 1998, Volume 1) states that the canister would be pressurized to as much as 4 psig to facilitate leak testing the canister after closure. Assuming the shipping conditions inside the shipping cask are the same as those for PWR fuel, the temperature during shipment would be 300°C. At this temperature, using the ideal gas law, the internal pressure inside the canister would be approximately 36 psia. Assuming the void volume around the canister is small relative to the void volume inside the canister and assuming the impact is sufficient to fail the canister, then the first expansion term becomes:

$$f_{e1} = \left[\frac{1.00 * 573}{2.45 * 623}\right] = 0.376$$

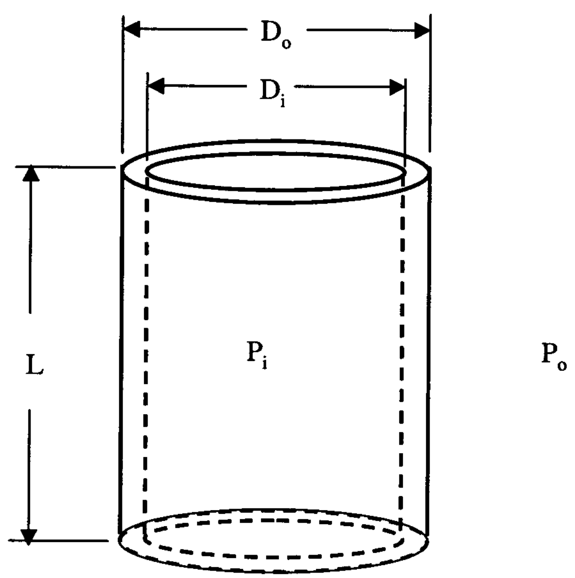
In this calculation, the pressure is expressed in atmospheres, 1.0 being the external pressure outside the cask and 2.45 being the pressure inside the canister during shipping. The temperatures are expressed in degrees Kelvin as required by the ideal gas law. The temperature of 623°K (350°C) is the assumed seal failure temperature. In DIRS 152476 (Sprung, et al, 2000, Chapter 7), the impact-only bin is assumed to include any cask releases up to the point where the seal fails; thus, the calculation conservatively uses 623°K to estimate the first expansion factor.

The fraction released is $[1-f_{e1}]$. If only a fraction of the canisters fails on impact, the fraction released is reduced accordingly. Thus, the maximum fraction released is [1-0.376] = 0.624. If only half of the canisters failed, the fraction of the gas released would decrease to 0.312.

Appendix E

Stress Calculation for DOE Spent Fuel Canister Heated to 1,000ºC (1,273ºK)

Several DOE spent nuclear fuel types could be shipped in DOE spent fuel canisters (DIRS 103230-DOE 1999, all). This canister has not been designed or tested to ensure that it will not fail in the severe transportation accident environment. Using the model developed in DIRS 152476 (Sprung et al. 2000, Chapter 7), should the canister not fail on impact and then fail in the fire when heated to 1,000°C, the release would actually be greater than if it had failed on impact because the pressure would be higher and fission products such as cesium would be more volatile. To quantify the difference, at the time of impact the built-up pressure from thermal expansion would be 2.45 atmospheres. This pressure was estimated using the ideal gas law and assuming the temperature during transport is 300°C and the temperature at the time of closure was 27°C (300°K). At 1,000°C, the internal pressure would rise to 5.4 atmospheres, about 65 psig. This pressure assumes that the backfill pressure would be 4 psig at the time of closure.



Assuming a canister that has an outside radius of 23 centimeters (9 inches) and a wall thickness of 0.375-inch, then the equations to determine the wall stress are as follows:

$$\sigma_{t\max} = P_i\left[\frac{r_o^2 + r_i^2}{r_o^2 - r_i^2}\right] \qquad \sigma_{s\max} = P_i\left[\frac{r_o^2}{r_o^2 - r_i^2}\right] \qquad \text{and} \qquad \sigma_{r\max} = P_i$$

These two stresses are combined using the following equation:

$$\sigma_{total} = \sqrt{\sigma_{t\max}^2 + \sigma_{s\max}^2 + \sigma_{r\max}^2}$$

When the radii and internal pressure of 65 psig are used, the resultant total stress is 1,725 psia. The ultimate tensile strength of 310S steel at 980°C (1,800°F) is 13,000 psia. For 304 stainless steel, the ultimate tensile strength is 9,900 psia. Looking in the literature, the lowest number that could be found for any type of steel is 8,000 psia. Thus, there is a safety factor of 4.6 between the stresses in the wall of the canister and the ultimate strength of the canister at 1,000°C. "N" failure is expected.

Appendix F
Development of Nevada County Vehicle Densities

The Annual Report of the Nevada Department of Transportation (DIRS 156930-2000, all) gives the following 24-hour traffic counts for interstate and U.S. primary highways in Nevada, as shown in Tables F-1 to F-15. The 24-hour traffic counts for all stations in a county in the same population zone (rural, suburban, or urban) were averaged to obtain a 24-hour average for that zone. The 24-hour average was divided by 24 to give the average number of vehicles per hour (vehicle density) traveling in both directions in each population zone in each county. This average was then divided by two to give the one-way vehicle density: the number shown in Table 4-6 and used in RADTRAN. Only traffic counts on interstate highways and primary U S. highways were used, and on-ramp/off-ramp counts were not used. Population density zones were defined as described in Section 3.2. In all of the tables, numbers have been rounded to the next largest whole number.

Table F-1. Carson County.

Station	Rural	Suburban	Urban
1			43,500
27	25,100		
28	23,000		
172		26,000	
44	20,800		
2521109		31,872	
2521209		11,396	
150		23,700	
Average	22,967	23,242	43,500

Table F-2. Churchill County. (1 of 2)

Station	Rural	Suburban
3	8,700	
4	6,600	
5		10,200
7		10,800
8		13,900
10		14,000
12		17,000
16		11,500
19		10,300
20		7,700
21		8,400
24		6,300
25	3,600	
27	1,050	
29	1,200	
30	1,300	
32	850	
34	800	
36	680	
53		8,050
54	2,350	
58	2,300	
59	4,300	
87		5,300

Table F-2. Churchill County.(2 of 2)

Station	Rural	Suburban
88		2,450
93	7,600	
97	6,740	
126		21,600
127	6,800	
121109	4,925	
122109	2,267	
123109		20,582
862	6,530	
Average	3,651	11,205

Table F-3. Clark County. (1 of 2)

Station	Rural	Suburban	Urban
52			155,500
61			200,700
67			207,200
74			223,300
87			21,500
96			169,200
92			221,000
98			105,955
101			170,240
113			146,300
129		117,500	
131		91,700	
193	8,200		
199	16,700		
221	8,200		
225	16,500		
226	15,400		
228	14,900		
230		38,500	
235	6,850		
242	2,420		
289			195,700
322			188,400
323			192,600
367	7,200		
374	5,200		
375	3,700		
378		21,500	
387		57,000	
409		27,000	
424			116,000
441	15,900		
453		60,900	
713		57,200	
715		76,600	
716			102,600
718			122,000
719			182,450

Table F-3. Clark County. (2 of 2)

Station	Rural	Suburban	Urban
720	31,000		
728	40,700		
729	17,800		
730	17,050		
784			148,200
798			123,100
799			123,700
814			120,450
819			101,750
831		77,200	
840	38,200		
841	39,800		
842	40,500		
843		22,600	
844	16,700		
845	16,700		
846	16,700		
847	15,700		
848	15,800		
849	15,800		
850	15,800		
896		60,850	
912		41,950	
933		76,200	
1021			146,300
1135	6,420		
312129	7,980		
311109	32,816		
311209	18,135		
Average	17,493	59,050	151,485

Table F-4. Douglas County. (1 of 2)

Station	Rural	Suburban
1	3,900	
2	4,700	
5	6,800	
6		22,700
7		23,200
8		26,500
9		26,500
10		24,200
11		24,300
29		26,600
30		27,300
31		27,000
33	27,700	
36		12,700
37		12,700
38		18,300
40	20,300	
41	23,000	

Table F-4. Douglas County. (1 of 2)

Station	Rural	Suburban
44		27,800
531109	6,091	
45	37,600	
67	25,000	
69	10,000	
Average	14,400	22,667

Table F-5. Elko County.

Station	Rural	Suburban
99	6,820	
112	6,570	
131	1,000	
144	4,790	
148	520	
155	790	
163		8,270
165		5,210
171		4,790
185		4,780
251		6,865
258		9,810
261		10,330
268		9,350
292		6,460
303		6,290
311		4,630
348		7,700
350		6,970
351	5,240	
352	4,785	
711209	5,291	
752209		10,045
752309		7,051
354	1,700	
Average	3,751	7,237

Table F-6. Esmeralda County.

Station	Rural
5	1,850
6	2,300
7	1,900
9	2,100
11	1,800
12	1,750
13	1,950
18	1,600
19	390
921109	1,916
20	200
Average	1,614

Table F-7. Eureka County.

Station	Rural
9	6,770
18	7,040
38	720
39	1,200
51	650
56	7,060
57	6,550
Average	4,284

Table F-8. Humboldt County.

Station	Rural	Suburban
1		6,850
18		6,870
10		6,730
22		12,400
23		12,600
25		13,700
26		13,318
106	5,200	
107	3,050	
110	1,700	
114	1,550	
155		5,230
163		6,750
176	7,220	
177	6,550	
178	6,430	
179	6,430	
180	6,430	
181	6,800	
182	6,800	
186	2,100	
1311109	7,188	
194	1,450	
Average	4,921	9,383

Table F-9. Lander County.

Station	Rural	Suburban
7		6,520
31	670	
33	1,100	
34	1,200	
37	790	
38	550	
48		6,350
58		6,820
66		6,430
Average	862	6,530

Table F-10. Lyon County.

Station	Rural	Suburban
1		18,200
2		15,600
6		15,600
12		14,400
13		10,200
16	6,000	
17	5,000	
18	3,850	
19	5,200	
20	2,000	
21	4,500	
22	6,700	
23		10,200
24		10,200
25		9,400
32		11,000
34		7,200
36		15,600
42	6,950	
44	3,000	
47	2,800	
48	3,000	
49	4,400	
51	5,300	
52	4,800	
53	4,250	
55	3,600	
111	2,300	
113	1,200	
114		14,400
115	3,500	
Average	4,124	12,667

Table F-11. Mineral County.

Station	Rural	Suburban
1	1,200	
2	2,000	
4	2,650	
5	3,500	
9		3,400
10		4,300
13		6,300
15	5,100	
16	2,700	
27	2,250	
30	2,200	
31		
32		
35	1,000	
38	1,500	
Average	2,410	4,667

Table F-12. Nye County.

Station	Rural	Suburban
18		
19	2,700	
21	2,350	
22		4,650
27		3,650
28		2,700
29		2,150
31		6,150
32		8,200
33		9,500
34		4,500
49		2,300
50	1,500	
60	670	
61	450	
63	420	
64	340	
65	200	
66	210	
69	250	
71	300	
	220	
Average	801	4,867

Table F-13. Pershing County.

Station	Rural	Suburban
136		6,780
142	7,200	
154	6,950	
155	6,840	
156	6,830	
157	6,810	
158	6,190	
Average	6,803	6,780

Table F-14. Washoe County. (1 of 2)

Station	Rural	Suburban	Urban
13			16,770
32			19,455
70		22,310	
71		21,060	
78		20,500	
86		20,320	
108		20,320	
116		19,480	
132		32,500	
134		36,500	
135		38,000	
138		47,800	
139		22,200	
401		29,060	

Table F-14. Washoe County. (2 of 2)

Station	Rural	Suburban	Urban
402		28,825	
418		49,140	
432			92,180
439			109,760
461			145,120
458			106,800
461			145,120
937		33,845	
913		22,890	
805		31,140	
806		37,350	
807		35,100	
808			103,550
809			92,400
810		54,665	
811		20,270	
812		20,270	
461			131,130
462			82,485
468		48,760	
481		15,060	
607	10,200		
620		30,885	
462			94,250
468		55,300	
481			15,600
629			142,000
634			136,250
651			98,500
671	35,040		
776			67,450
804		28,735	
Average	22,620	31,196	94,048

Table F-15. White Pine County. (1 of 2)

Station	Rural	Suburban
5	500	
16	3,000	
17	2,050	
18		5,450
47	2,850	
20		9,550
23		11,300
26		7,450
56	1,350	
57	1,000	
58	1,550	
62	1,300	
63	370	
69	2,000	
70	2,800	
73	990	

Table F-15. White Pine County. (2 of 2)

Station	Rural	Suburban
75	4,850	
25		7,500
Average	1,893	8,250

Appendix G
Estimates of Materials Transported to the Repository, Workers Traveling to the Repository, and Site Generated Waste Transported From the Repository

Materials transported to the repository: fossil fuels.

Fossil Fuel (million liters) Phase/Activity Durations- (years	**Low-Temp w/o Aging 6.4m Space**	**Low-Temp w/o Aging 300 yr PE Vent**	**Low-Temp w/Aging 6.4m Space**	**Low-Temp w/Aging 300 yr PE Vent**	**Low-Temp Small or De-rated WP**	**Low-Temp Natural Ventilation**
Construction	5	5	5	5	5	5
Operations and monitoring	149	324	149	324	324	324
Closure	17	11	17	11	12	11
Post-emplacement used for Project total	125	300	112	287	300	50/250
Construction	5.75	5.90	5.45	5.60	6.05	5.90
Subsurface	1.95	2.10	1.95	2.10	2.10	2.10
Surface	3.80	3.80	3.50	3.50	3.95	3.80
Operations and monitoring	379.61	385.60	403.11	409.05	400.65	377.40
Development	13.90	7.90	13.90	7.90	8.65	7.90
Emplacement/transfer-3,000 MTHM/yr	312.50	312.50	287.54	287.54	324.98	312.50
Subsurface	0.50	0.50	0.50	0.50	0.50	0.50
Surface	312.00	312.00	287.04	287.04	324.48	312.00
Aging						
Emplacement from aging-3,000 MTHM/yr			49.27	49.27		
Decontamination	45.40	45.40	45.40	45.40	45.40	45.40
Monitoring 125 PE or 112 PE years	7.81		7.00			
Subsurface	7.81		7.00			
Surface	Minimal		Minimal			
300 PE or 287 PE years		19.80		18.94	21.62	
Subsurface		19.80		18.94	21.62	
Surface		Minimal		Minimal	Minimal	
50 years PE						3.30
Subsurface						3.30
Surface						Minimal
250 years natural ventilation						8.30
Subsurface						8.30
Surface						Minimal
Closure	6.69	6.39	6.39	6.09	6.79	6.39
Subsurface	3.00	2.70	3.00	2.70	2.95	2.70
Surface	3.69	3.69	3.39	3.39	3.84	3.69
Project total	**392**	**398**	**415**	**421**	**413**	**390**

Materials transported to the repository: oils and lubricants.

Oils and Lubricants (million liters)	Low-Temp w/o Aging 6.4m Space	Low-Temp w/o Aging 300 yr PE Vent	Low-Temp w/Aging 6.4m Space	Low-Temp w/Aging 300 yr PE Vent	Low-Temp Small or De-rated WP	Low-Temp Natural Ventilation
Construction	3.10	3.50	3.09	3.49	3.50	3.30
Subsurface	3.00	3.40	3.00	3.40	3.40	3.20
Surface	0.10	0.10	0.09	0.09	0.10	0.10
Operations and monitoring	51.78	121.10	50.13	117.54	131.98	73.20
Development	23.00	13.10	23.00	13.10	14.31	13.10
Emplacement/transfer-3,000 MTHM/yr	3.00	3.00	3.00	3.00	3.00	3.00
Subsurface	3.00	3.00	3.00	3.00	3.00	3.00
Surface	0.00	0.00	0.00	0.00	0.00	0.00
Aging						
Emplacement from aging-3,000 MTHM/yr			1.03	0.99		
Decontamination	0.00	0.00	0.00	0.00		
Monitoring 125 PE or 112 PE years	25.78		23.10			
Subsurface	25.78		23.10			
Surface	Minimal		Minimal			
300 PE or 287PE years		105.00		100.45	114.67	
Subsurface		105.00		100.45	114.67	
Surface		Minimal		Minimal	Minimal	
50 years PE						18
Subsurface						18
Surface						Minimal
250 years natural ventilation						40
Subsurface						40
Surface						Minimal
Closure	3.10	2.90	3.09	2.89	3.16	2.90
Subsurface	3.00	2.80	3.00	2.80	3.06	2.80
Surface	0.10	0.10	0.09	0.09	0.10	0.10
Project total	**58**	**128**	**56**	**124**	**139**	**79**

Materials transported to the repository: cement, sand and aggregate, steel, copper

	Time-yr	Low-Temp w/o Aging 6.4m Space	Low-Temp w/o Aging 300 yr PE Vent	Low-Temp w/Aging 6.4m Space	Low-Temp w/Aging 300 yr PE Vent	Low-Temp Small or De-rated WP	Low-Temp Natural Ventilation
Cement-(1,000 metric tons)							
Construction	2005-2010	183.2	182.9	186.9	186.6	156.0	182.9
Subsurface	2005-2010	113.0	112.7	113.0	112.7	83.0	112.7
Surface	2005-2010	70.2	70.2	73.9	73.9	73.0	70.2
Operations and Monitoring							
Development	2010-2031	260.5	138.2	260.5	138.2	157.3	138.2
Emplacement(and Aging)							
Subsurface	2010-2033	0.4	0.4	0.4	0.4	0.6	0.4
Surface-Aging Pad	2010-2030			37.4	37.4		
Surface-Dry Storage Cask	2010-2030			45.1	45.1		
Decontamination							
Monitoring							
Closure	(Varies)						
Subsurface	(Varies)	1.2	1.2	1.2	1.2	1.9	1.2
Surface							
Project Total		**445**	**323**	**532**	**409**	**316**	**323**
Sand and Aggregate (1000 metric tons)							
Construction	2005-2010	305	304	298	297	264	304
Subsurface	2005-2010	173	172	173	172	127	172
Surface	2005-2010	132	132	126	126	137	132
Operations and Monitoring							
Development	2010-2031	395	211	395	211	296	211
Emplacement(and Aging)							
Subsurface	2010-2033						
Surface-Aging Pad	2010-2030			57	57		
Surface-Dry Storage Cask	2010-2030			85	85		
Decontamination							
Monitoring							
Closure	(Varies)						
Subsurface	(Varies)	2	2	2	2	3	2
Surface							
Project Total		**701**	**516**	**836**	**651**	**563**	**516**
Steel-(1,000 metric tons)							
Construction	2005-2010	121.2	120.2	119.2	118.2	102.5	120.2
Subsurface	2005-2010	72.4	71.4	72.4	71.4	51.7	71.4
Surface	2005-2010	48.8	48.8	46.8	46.8	50.8	48.8
Operations and Monitoring							

Development	2010-2031	164.6	145.1	164.6	145.1	134.6	145.1
Emplacement(and Aging)							
Subsurface	2010-2033						
Surface-Aging Pad	2010-2030			13.2	13.2		
Surface-Dry Storage Cask	2010-2030						
Decontamination							
Monitoring							
Closure	(Varies)	0.04	0.04	0.04	0.04	0.04	0.04
Subsurface	(Varies)	0.04	0.04	0.04	0.04	0.04	0.04
Surface							
Project Total		**286**	**265**	**297**	**276**	**237**	**267**
***Copper-**(1,000 metric tons)*							
Construction	2005-2010	0.23	0.23	0.23	0.23	0.16	0.23
Subsurface	2005-2010	0.225	0.231	0.225	0.231	0.162	0.231
Surface	2005-2010						
Operations and Monitoring							
Development	2010-2031	0.241	0.55	0.241	0.55	0.200	0.55
Emplacement							
Decontamination							
Monitoring							
Closure							
Project Total		**0.47**	**0.78**	**0.47**	**0.78**	**0.36**	**0.78**

Workers commuting to the repository – Proposed Action

			Lower temperature						
			Long-term ventilation					Maximum spacing	
	Flexible Design		No aging		Aging	Natural circulation	Derated (smaller) waste package	No aging	Aging
Phase	**UC[a]**	**DPC[b]**	**UC**	**DPC**	**UC**	**UC**	**UC**	**UC**	**UC**
Construction	2,819	2,477	2,819	2,477	2,593	2,819	2,932	2,819	2,593
	1,072	943	1,072	943	986	1,072	1,115	1,072	986
	2,730	2,730	2,730	2,730	2,730	2,730	2,730	2,730	2,730
	560	560	560	560	560	560	560	560	560
	76	76	76	76	76	76	76	76	76
	26	26	26	26	26	26	26	26	26
	NA[d]	NA	NA	NA	1,307	NA	NA	NA	1,307
	NA	NA	NA	NA	498	NA	NA	NA	498
	7,283	6,812	7,283	6,812	8,776	7,283	7,439	7,283	8,776
Operations	23,136	14,736	23,136	14,736	23,496	23,136	24,096	23,136	23,496
	8,184	9,336	8,184	9,336	8,208	8,184	8,184	8,184	8,208
	NA	NA	NA	NA	12,727	NA	NA	NA	12,727
	NA	NA	NA	NA	4,446	NA	NA	NA	4,446
	1,776	1,776	1,776	1,776	1,776	1,776	2,451	1,776	1,776
	384	384	384	384	384	384	530	384	384
	NA	NA	NA	NA	1,924	NA	NA	NA	1,924
	NA	NA	NA	NA	416	NA	NA	NA	416
	6,160	6,160	6,600	6,600	6,600	6,600	6,600	7,480	7,480
	2,002	2,002	2,200	2,200	2,200	2,200	2,200	2,200	2,200
	41,642	34,394	42,280	35,032	62,177	42,280	44,061	43,160	63,057
Monitoring	2,663	1,973	2,663	1,973	2,663	2,663	2,190	2,663	2,663
	689	605	689	605	689	689	605	689	689
	2,555	2,555	10,395	10,395	9,485	10,395	10,395	4,270	3,360
	0	0	0	0	0	0	0	0	0
	5,244	5,244	20,700	20,700	18,906	8,450	20,700	8,625	6,831
	988	988	3,900	3,900	3,562	2,150	3,900	1,625	1,287
	180	180	583	583	583	583	583	268	268
	36	36	144	144	144	144	144	63	63
	12,355	11,581	39,074	38,300	36,032	25,074	38,517	18,203	15,161
Closure	2,852	2,508	2,852	2,508	2,852	2,852	2,852	2,852	2,852
	1,085	954	1,085	954	1,085	1,085	1,085	1,085	1,085
	2,380	2,380	2,618	2,618	2,618	2,618	2,856	4,046	4,046
	450	450	495	495	495	495	540	765	765
	62	62	62	62	62	62	62	62	62
	24	24	24	24	24	24	24	24	24
	6,853	6,378	7,136	6,661	7,136	7,136	7,419	8,834	8,834
Totals	68,133	59,165	95,773	86,805	113,348	81,773	97,436	77,480	95,055

Workers commuting to the repository – Modules 1 and 2.

			Lower temperature						
			Long-term ventilation					Maximum spacing	
	Flexible Design		No aging		Aging	Natural circulation	Derated (smaller) waste package	No aging	Aging
Phase	**UC[a]**	**DPC[b]**	**UC**	**DPC**	**UC**	**UC**	**UC**	**UC**	**UC**
Construction	2,819	2,477	2,819	2,477	2,593	2,819	2,932	2,819	2,593
	1,072	943	1,072	943	986	1,072	1,115	1,072	986
	2,730	2,730	2,730	2,730	2,730	2,730	2,730	2,730	2,730
	560	560	560	560	560	560	560	560	560
	76	76	76	76	76	76	76	76	76
	26	26	26	26	26	26	26	26	26
	NA[d]	NA	NA	NA	747	NA	NA	NA	747
	NA	NA	NA	NA	285	NA	NA	NA	285
	7,283	6,812	7,283	6,812	8,003	7,283	7,439	7,283	8,003
Operations	23,136	14,736	23,136	14,736	23,496	23,136	24,096	23,136	23,496
	8,184	9,336	8,184	9,336	8,208	8,184	8,184	8,184	8,208
	NA	NA	NA	NA	12,727	NA	NA	NA	12,727
	NA	NA	NA	NA	4,446	NA	NA	NA	4,446
	1,776	1,776	1,776	1,776	1,776	1,776	2,451	1,776	1,776
	384	384	384	384	384	384	530	384	384
	NA	NA	NA	NA	1,924	NA	NA	NA	1,924
	NA	NA	NA	NA	416	NA	NA	NA	416
	6,160	6,160	6,600	6,600	6,600	6,600	6,600	7,480	7,480
	2,002	2,002	2,200	2,200	2,200	2,200	2,200	2,200	2,200
	41,642	34,394	42,280	35,032	62,177	42,280	44,061	43,160	63,057
Monitoring	2,663	1,973	2,663	1,973	2,663	2,663	2,190	2,663	2,663
	689	605	689	605	689	689	605	689	689
	2,555	2,555	10,395	10,395	9,485	10,395	10,395	4,270	3,360
	0	0	0	0	0	0	0	0	0
	5,244	5,244	20,700	20,700	18,906	8,450	20,700	8,625	6,831
	988	988	3,900	3,900	3,562	2,150	3,900	1,625	1,287
	180	180	583	583	583	583	583	268	268
	36	36	144	144	144	144	144	63	63
	12,355	11,581	39,074	38,300	36,032	25,074	38,517	18,203	15,161
Closure	2,852	2,508	2,852	2,508	2,852	2,852	2,852	2,852	2,852
	1,085	954	1,085	954	1,085	1,085	1,085	1,085	1,085
	2,380	2,380	2,618	2,618	2,618	2,618	2,856	4,046	4,046
	450	450	495	495	495	495	540	765	765
	62	62	62	62	62	62	62	62	62
	24	24	24	24	24	24	24	24	24
	6,853	6,378	7,136	6,661	7,136	7,136	7,419	8,834	8,834
Totals	68,133	59,165	95,773	86,805	113,348	81,773	97,436	77,480	95,055

Site-generated waste transported from the repository, maximum spacing, 125-year operation.

Source[a]	Phase	Construction/ demolition debris (cubic meters)	Sanitary/ industrial solid waste (cubic meters)	Hazardous waste (cubic meters)	Sanitary sewage (million liters)	Industrial wastewater (million liters)	Low-level waste (cubic meters)	Mixed waste (cubic meters)
125-year post-emplacement forced ventilation								
DIRS 153882 Griffith 2001 Solar Power, Tb SPS2, p.15	Construction	275.26	137.63	25.40	0.49	0.00	0.00	0.00
	Closure	6994.56	131.51	24.77	0.49	0.00	0.00	0.00
DIRS 155515 Williams 2001 Subsurface (Option 1)	Construction	0.00	5000.00	0.00	155.62	42.50	0.00	0.00
	Dev. of emplacement		22000.00	0.00	457.86	165.00	0.00	0.00
	Emplacement	0.00	4416.00	0.00	102.19	0.00	0.00	0.00
	Caretaker/ monitoring	0.00	25000.00	0.00	485.00	0.00	0.00	0.00
	Closure	0.00	5678.00	0.00	227.80	119.00	0.00	0.00
DIRS 152010 CRWMS M&O 2000 Surface, Note 1	Construction	4710.00	5950.00	1173.69	23.00	12.21	0.00	0.00
	Emplacement	0.00	34320.00	5819.18	890.40	818.40	67175.00	22.08
	Initial decon	0.00	4553.00	264.44	117.30	0.00	521.00	0.98
	Caretaker shutdown	0.00	658.80	0.00	24.89	0.00	0.00	0.00
	Closure	212320.00	6020.00	1139.97	23.00	0.00	3455.00	0.00
Totals	Grand total	224299.82	113864.94	8447.44	2508.04	1157.11	71151.00	23.06
	Construction total	4985.26	11087.63	1199.09	179.11	54.71	0.00	0.00
	Operation & monitoring total		90947.80	6083.62	2077.64	983.40	67696.00	23.06
	Closure total	219314.56	11829.51	1164.74	251.29	119.00	3455.00	0.00
Number of offsite shipments to TSDFs	Construction total	191.34	Included in construction debris	72.06	NA	NA	0.00	0.00
	Operation & monitoring total		Included in construction debris	365.60	NA	NA	1781.47	1.39
	Closure total	2751.72	Included in construction debris	70.00	NA	NA	90.92	0.00
DIRS 152010 CRWMS M&O 2000 Surface Ap.I Tb 1-2, revised	Retrieval construction, Note 2	13391.00	2760.00	522.31	11.00	0.00	0.00	0.00
Note 3 and 4	Retrieval operation	0.00	1301.79	0.00	33.77	0.00	1617.00	0.00
DIRS 155515 Williams 2001 Subsurface	Retrieval operation	0.00	3600.00	0.00	51.10	0.00	0.00	0.00
	Retrieval operation total	0.00	4901.79	0.00	84.87	0.00	1617.00	0.00

Note 1: Industrial WW from concrete batch plant, assumed 10 trucks for first 5 years, 3 trucks for next 22 years rinsed with 200 liters and plant rinsed with 950 liters for 27 years, 250 days per year

Note 2: HW calculated using ratio or construction debris to HW found in Surface EF Construction waste, Table 6-1

Note 3: Used emplacement sanitary solid waste basis for retrieval operation because emplacement activities were more like retrieval than construction, decon, caretaking, or closure

Note 4: Retrieval ops LLW calculated based on aging to emplacement formula scaling 40,000 MTHT to 70,000 and substituting 11 years for 20

Site-generated waste transported from the repository, maximum spacing, 125-year operation with aging.

Phase	Construction/ demolition debris (cubic meters)	Sanitary/ industrial solid waste (cubic meters)	Hazardous waste (cubic meters)	Sanitary sewage (million liters)	Industrial wastewater (million liters)	Low-level waste (cubic meters)	Mixed waste (cubic meters)
	surface aging & 125 years postemplacement forced ventilation						
Construction	275.26	137.63	25.40	0.49	0.00	0.00	0.00
Closure	6994.56	131.51	24.77	0.49	0.00	0.00	0.00
Construction	0.00	5000.00	0.00	155.62	42.50	0.00	0.00
Dev. of emplacement		22000.00	0.00	457.86	165.00	0.00	0.00
Emplacement	0.00	4416.00	0.00	102.19	0.00	0.00	0.00
Aging & monitoring	0.00	1104.00	0.00	25.55	0.00	0.00	0.00
Aging to emplacment		3680.00	0.00	85.16	0.00	0.00	0.00
Caretaker/monitoring		19800.00	0.00	384.12	0.00	0.00	0.00
Closure	0.00	5678.00	0.00	227.80	119.00	0.00	0.00
Construction	4333.20	5474.00	1079.80	21.16	14.41	0.00	0.00
Emplacement	0.00	34740.78	5353.65	901.32	752.93	67175.00	22.08
Aging & monitoring	0.00	4342.60	0.00	112.66	0.00	0.00	0.00
Aging to emplacment		14475.33	0.00	375.55	0.00	0.00	0.00
Initial decon	0.00	4188.76	243.28	107.92	0.00	479.32	0.90
Caretaker shutdown		476.93	0.00	18.02	0.00	0.00	0.00
Closure	195334.40	5538.40	1048.77	21.16	0.00	3178.60	0.00
Aging facility construction		0.00	1166.55	0.00	0.00	0.00	0.00
Aging facility operation		0.00	0.00	0.00	0.00	0.00	0.00
Aging facility closure		0.00	0.00	0.00	0.00	0.00	0.00
Grand total	444914.51	131183.93	8942.22	2997.07	1093.84	70832.92	22.98
Construction total	9274.67	10611.63	2271.75	177.27	56.91	0.00	0.00
Operation & monitoring total		109224.39	5596.93	2570.35	917.93	67654.32	22.98
Closure total	435639.83	11347.91	1073.54	249.45	119.00	3178.60	0.00
Construction total	236.74	Included with construction debris	136.52	NA	NA	0.00	0.00
Operation & monitoring total		Included with construction debris	336.35	NA	NA	1780.38	1.38
Closure total	5321.28	Included with construction debris	64.52	NA	NA	83.65	0.00

Site-generated waste transported from the repository, maximum ventilation, 324-year operation.

Source[a]	Phase	Construction/ demolition debris (cubic meters)	Sanitary/ industrial solid waste (cubic meters)	Hazardous waste (cubic meters)	Sanitary sewage (million liters)	Industrial wastewater (million liters)	Low-level waste (cubic meters)	Mixed waste (cubic meters)
300 years post-emplacement forced ventilation								
DIRS 153882 Griffith 2001	Construction	275.26	137.63	25.40	0.49	0.00	0.00	0.00
	Closure	6994.56	131.51	24.77	0.49	0.00	0.00	0.00
DIRS 155515 Williams 2001	Construction	0.00	5000.00	0.00	155.62	45.00	0.00	0.00
	Dev. of emplacement	0.00	22000.00	0.00	416.24	96.23	0.00	0.00
	Emplacement	0.00	4416.00	0.00	102.19	0.00	0.00	0.00
	Caretaker/ monitoring	0.00	60000.00	0.00	1163.70	0.00	0.00	0.00
	Closure	0.00	3674.00	0.00	147.25	77.00	0.00	0.00
DIRS 152010 CRWMS M&O 2000 Surface, Note 1	construction	4710.00	5950.00	1173.69	23.00	12.21	0.00	0.00
	Emplacement	0.00	34320.00	5819.18	890.40	818.40	67175.00	22.08
	Initial decon	0.00	4553.00	264.44	117.30	0.00	521.00	0.98
	Caretaker shutdown	0.00	1603.80	0.00	60.59	0.00	0.00	0.00
	Closure	212320.00	6020.00	1139.97	23.00	0.00	3455.00	0.00
Totals	Grand total	224299.82	147805.94	8447.44	3100.27	1048.84	71151.00	23.06
	Construction total	4985.26	11087.63	1199.09	179.11	57.21	0.00	0.00
	Operation & monitoring total	0.00	126892.80	6083.62	2750.42	914.63	67696.00	23.06
	Monitoring & caretaking total		66156.80		1341.59			
	Closure total	219314.56	9825.51	1164.74	170.74	77.00	3455.00	0.00
Number of offsite shipments to TSDFs	Construction total	191.34	Included in construction debris	72.06	NA	NA	0.00	0.00
	Operation & monitoring total	1510.63	Included in construction debris	365.60	NA	NA	1781.47	1.39
	Closure total	2727.86	Included in construction debris	70.00	NA	NA	90.92	0.00
DIRS 152010 CRWMS M&O 2000 Surface	Retrieval construction	13391.00	2760.00	522.31	11.00	0.00	0.00	0.00

Note 1: Industrial WW, assumed 10 trucks serving concrete batch plant that are rinsed with 200 liters of water/day for 250 days/yr, 5 yrs; than just 3 trucks for 22 years

Assumed 950 liters of rinsewater for the concrete batch plant for 250 days/yr for 27 years

Site-generated waste transported from the repository, maximum ventilation, 324-year operation with aging.

Source[a]	Phase	Construction/ demolition debris (cubic meters)	Sanitary/ industrial solid waste (cubic meters)	Hazardous waste (cubic meters)	Sanitary sewage (million liters)	Industrial wastewater (million liters)	Low-level waste (cubic meters)	Mixed waste (cubic meters)
300 years post-emplacement forced ventilation and surface aging								
DIRS 153882 Griffith 2001	Construction	275.26	137.63	25.40	0.49	0.00	0.00	0.00
	Closure	6994.56	131.51	24.77	0.49	0.00	0.00	0.00
DIRS 155515 Williams 2001 Subsurface	Construction	0.00	5000.00	0.00	155.62	45.00	0.00	0.00
	Dev. of emplacement	0.00	22000.00	0.00	416.24	96.23	0.00	0.00
	Emplacement	0.00	4416.00	0.00	102.19	0.00	0.00	0.00
	Aging & monitoring	0.00	1104.00	0.00	25.55	0.00	0.00	0.00
	Aging to emplacement		3680.00	0.00	85.16	0.00	0.00	0.00
	Caretaker/ monitoring	0.00	54800.00	0.00	1062.85	0.00	0.00	0.00
	Closure	0.00	3674.00	0.00	147.25	77.00	0.00	0.00
DIRS 152010 CRWMS M&O 2000 Surface, Note 2	construction	4333.20	5474.00	1079.80	21.16	14.41	0.00	0.00
See page G-5 for number of workers	Emplacement	0.00	34740.78	5353.65	901.32	752.93	67175.00	22.08
See page G-5 for number of workers	Aging & monitoring	0.00	4342.60	0.00	112.66	0.00	0.00	0.00
DIRS 155515 Williams 2001: LLW, page G-5: workers	Aging to emplacement		14475.33	0.00	375.55	0.00	0.00	0.00
	Initial decon	0.00	4188.76	243.28	107.92	0.00	479.32	0.90
	Caretaker shutdown	0.00	1346.33	0.00	50.86	0.00	0.00	0.00
	Closure	195334.40	5538.40	1048.77	21.16	0.00	3178.60	0.00
DIRS 152010 CRWMS M&O 2000 Surface, Note 1	Aging facility construction		0.00	1166.55	0.00	0.00	0.00	0.00
DIRS 155515 Williams 2001 Surface	Aging facility operation	0.00	0.00	0.00	0.00	0.00	0.00	0.00
See pp G-1 to G-4 for materials	Aging facility closure	233310.87	0.00	0.00	0.00	0.00	0.00	0.00
Totals	Grand total	444914.51	165049.33	8942.22	3586.46	985.57	70832.92	22.98
	Construction total	9274.67	10611.63	2271.75	177.27	59.41	0.00	0.00
	Operation & monitoring total		145093.79	5596.93	3240.29	849.16	67654.32	22.98
	Monitoring & caretaking total				1820.54			
	Closure total	435639.83	9343.91	1073.54	168.90	77.00	3178.60	0.00
Number of offsite shipments to TSDFs	Construction total	236.74	Included in construction	136.52	NA	NA	0.00	0.00
	Operation & monitoring total		Included in construction	336.35	NA	NA	1780.38	1.38
	Closure total	5297.43	Included in construction	64.52	NA	NA	83.65	0.00

Site-generated waste transported from the repository, derated casks, 324-year operation.

Source[a]	Phase	Construction/ demolition debris (cubic meters)	Sanitary/ industrial solid waste (cubic meters)	Hazardous waste (cubic meters)	Sanitary sewage (million liters)	Industrial wastewater (million liters)	Low-level waste (cubic meters)	Mixed waste (cubic meters)
DIRS 153882 Griffith 2001	Construction	275.26	137.63	25.40	0.49	0.00	0.00	0.00
	Closure	6994.56	131.51	24.77	0.49	0.00	0.00	0.00
DIRS 152010 CRWMS M&O 2000 Subsurface M1,2, Note 1	Construction	0.00	5000.00	0.00	155.62	45.25	0.00	0.00
DIRS 152010 CRWMS M&O 2000 Subsurface M1,2, Notes 1 & 2	Dev. of emplacement	0.00	22000.00	0.00	368.37	105.60	0.00	0.00
DIRS 152010 CRWMS M&O 2000 Subsurface M1,2, Note 2	Emplacement	0.00	4416.00	0.00	102.19	0.00	0.00	0.00
DIRS 152010 CRWMS M&O 2000 Subsurface M1,2 data	Caretaker/ monitoring	0.00	60000.00	0.00	1164.00	0.00	0.00	0.00
DIRS 155516 Williams 2001 Subsurface, sewage only	Closure	0.00	4080.00	0.00	160.63	84.00	0.00	0.00
Note 3, DIRS 152010 CRWMS M&O 2000 Surface	Construction	4898.40	6188.00	1220.64	23.92	12.21	0.00	0.00
DIRS 155516-Williams 2001 Surface, p. G-5: workers	Emplacement	0.00	35371.95	6051.95	917.69	851.14	90014.50	29.59
	Initial decon	0.00	3796.43	275.01	97.81	0.00	698.14	1.31
	Caretaker shutdown	0.00	1667.95	0.00	63.01	0.00	0.00	0.00
	Closure	220812.80	6260.80	1185.56	23.92	0.00	4629.70	0.00
Totals	Grand total	232981.02	149050.28	8783.33	3078.14	1098.20	95342.34	30.90
	Construction total	5173.66	11325.63	1246.04	180.03	57.46	0.00	0.00
	Operation & monitoring total		127252.34	6326.96	2713.07	956.74	90712.64	30.90
	Monitoring & caretaking total				1324.82			
	Closure total	227807.36	10472.31	1210.34	185.04	84.00	4629.70	0.00
Number of offsite shipments to TSDFs	Construction total	196.42	Included in construction	74.88	NA	NA	0.00	0.00
	Operation & monitoring total		Included in construction	380.23	NA	NA	2387.17	1.86
	Closure total	2836.66	Included in construction	72.74	NA	NA	121.83	0.00
DIRS 152010 CRWMS M&O 2000 Surface	Peak emplacement year			275.01				1.34

Site-generated waste transported from the repository, natural ventilation, 324-year operation.

Source[a]	Phase	Construction/ demolition debris (cubic meters)	Sanitary/ industrial solid waste (cubic meters)	Hazard ous waste (cubic meters)	Sanitary sewage (million liters)	Industrial wastewater (million liters)	Low-level waste (cubic meters)	Mixed waste (cubic meters)
300 years post emplacement forced ventilation								
DIRS 153882 Griffith 2001	Construction	275.26	137.63	25.40	0.49	0.00	0.00	0.00
	Closure	6994.56	131.51	24.77	0.49	0.00	0.00	0.00
DIRS 155515 Williams 2001 Subsurface	Construction	0.00	5000.00	0.00	155.62	45.00	0.00	0.00
	Dev. of emplacement	0.00	22000.00	0.00	416.24	96.23	0.00	0.00
	Emplacement	0.00	4416.00	0.00	102.19	0.00	0.00	0.00
	Caretaker/ monitoring forced vent	0.00	10000.00	0.00	193.95	0.00	0.00	0.00
	Caretaker/ monitoring natural cir	0.00	50000.00	0.00	307.48	0.00	0.00	0.00
	Closure	0.00	3674.00	0.00	147.25	77.00	0.00	0.00
DIRS 152010 CRWMS M&O 2000 Surface, Note1	Construction	4710.00	5950.00	1173.69	23.00	12.21	0.00	0.00
	Emplacement	0.00	34320.00	5819.18	890.40	818.40	67175.00	22.08
	Initial decon	0.00	4553.00	264.44	117.30	0.00	521.00	0.98
	Caretaker shutdown forced vent	0.00	253.80	0.00	9.59	0.00	0.00	0.00
	Caretaker shutdown natural cir	0.00	1350.00	0.00	51.00	0.00	0.00	0.00
DIRS 152010 CRWMS M&O 2000 Surface	Closure	212320.00	6020.00	1139.97	23.00	0.00	3455.00	0.00
Totals	Grand total	224299.82	147805.94	8447.44	2437.99	1048.84	71151.00	23.06
	Construction	4985.26	11087.63	1199.09	179.11	57.21	0.00	0.00
	Ops/monitoring	0.00	126892.80	6083.62	2088.15	914.63	67696.00	23.06
	Monitoring & caretaking 1		61603.80		562.01			
	Closure total	219314.56	9825.51	1164.74	170.74	77.00	3455.00	0.00
Number of offsite shipments to TSDFs	Construction total	191.34	Included in construction	72.06	NA	NA	0.00	0.00
	Operation & monitoring total	1510.63	Included in construction	365.60	NA	NA	1781.47	1.39
	Closure total	2727.86	Included in construction	70.00	NA	NA	90.92	0.00
DIRS 152010 CRWMS M&O 2000 Surface	Retrieval construction	13391.00	2760.00	522.31	11.00	0.00	0.00	0.00

Site-generated waste transported from the repository, flexible design, 100-year operation.

Phase	Construction/ demolition debris (cubic meters)	Sanitary/ industrial solid waste (cubic meters)	Hazardous waste (cubic meters)	Sanitary sewage (million liters)	Industrial wastewater (million liters)	Low-level waste (cubic meters)	Mixed waste (cubic meters)
Construction	4710.00	5950.00	1173.69	23.00	12.21	0.00	0.00
Emplacement	0.00	34320.00	5819.18	890.40	818.40	67175.00	22.08
Initial decon	0.00	4553.00	264.44	117.30	0.00	521.00	0.98
Caretaker shutdown	0.00	394.20	0.00	14.89	0.00	0.00	0.00
Closure	212320.00	6020.00	1139.97	23.00	0.00	3455.00	0.00
Construction	0.00	5000.00	0.00	155.62	34.00	0.00	0.00
Dev. of emplacement	0.00	22000.00	0.00	386.10	77.00	0.00	0.00
Emplacement	0.00	4416.00	0.00	102.19	0.00	0.00	0.00
Caretaker/monitoring	0.00	15200.00	0.00	294.88	0.00	0.00	0.00
Closure	0.00	3340.00	0.00	133.86	70.00	0.00	0.00
Construction	275.26	137.63	25.40	0.49	0.00	0.00	0.00
Closure	6994.56	131.51	24.77	0.49	0.00	0.00	0.00
Construction total	4985.26	11087.63	1199.09	179.11	46.21	0.00	0.00
Operation & monitoring total	0.00	80883.20	6083.62	1805.76	895.40	67696.00	23.06
Caretaker monitoring total		20147.20		427.07			
Closure total	219314.56	9491.51	1164.74	157.35	70.00	3455.00	0.00
Grand total	224299.82	101462.34	8447.44	2142.22	1011.61	71151.00	23.06
Construction total	191.34	included in construction	72.06	NA	NA	0.00	0.00
Operation & monitoring total	962.90	included in construction	365.60	NA	NA	1781.47	1.39
Closure total	2723.88	included in construction	70.00	NA	NA	90.92	0.00

Appendix H
Impacts of Using 2000 Census Population Data

H.1 Introduction

The purpose of this appendix is to present the impacts of using 2000 census population data on the transportation results presented in the EIS. This appendix presents the results for truck and rail transportation to the repository for the Proposed Action. For rail, only the Caliente heavy-haul truck Nevada implementing alternative was evaluated.

H.2 Method

The methods and data used in this analysis were the same as were previously described in the transportation calculation package, except for the population data. WebTRAGIS (DIRS 157136-Johnson and Michelhaugh 2000, all) was used to perform the national transportation routing analysis instead of HIGHWAY (DIRS 104780-Johnson et al. 1993a, all) and INTERLINE (DIRS 104781-Johnson et al. 1993b, all), because WebTRAGIS contains 2000 census population data and HIGHWAY and INTERLINE do not. The WebTRAGIS output is in Attachment 34A. The 2000 census Nevada population data were developed using the same methods described in Section 3.3 of the transportation calculation package. Escalation factors were developed for the year 2000 to 2035 were estimated using the same methods described in Section 3.4 of the transportation calculation package.

H.3 Assumptions

The assumptions used in this analysis were the same as were previously described in the transportation calculation package, except that 2000 census population data were used.

H.4 Use of Computer Software and Models

The computer software and models used in this analysis were the same as were previously described in the transportation calculation package, except that WebTRAGIS (DIRS 157136-Johnson and Michelhaugh 2000, all) was used to perform the national transportation routing analysis. WebTRAGIS is a client/server system; the client software is downloadable from http://apps.ntp.doe.gov/tragis/tragis.htm.

H.5 Calculation/Analysis and Results

Attachment 34A contains the electronic files used in this analysis. The population escalation factors for the year 2000 through 2035 and the 2000 census Nevada truck routing data are contained in the file *2000 Census Update – LWT.xls*. The 2000 census Nevada rail and heavy-haul truck routing data contained in the file *caliente hh.xls*.

The detailed WebTRAGIS output is in the files *truck2000.dns*, *truck2000.wds*, *truck2000.lst*, *rail2000.dns*, *rail2000.wds*, and *rail2000.lst*. The files *truck2000.lst* and *rail2000.lst* list the node or link deletions used in the routing analysis. The formats of these files are described in Section 3.1 of the transportation calculation package. The Access data bases *FEIS Transportation Census LWT 2000.mdb* (for legal-weight trucks) and *FEIS Transportation Census Caliente 2000.mdb* (for rail) contain the Access data bases used to estimate the transportation impacts.

The results of the truck analysis are presented in Table H-1. There could be about 13.5 total fatalities associated with the national 1990 census-based results extrapolated to the year 2035. There could be about 14.0 total fatalities associated with the national 2000 census-based results extrapolated to the year 2035.

The total impacts of the Nevada 1990 census-based results extrapolated to the year 2035 could be 1.47 fatalities. The total impacts of the Nevada 2000 census-based results extrapolated to the 2035 could be 1.46 fatalities.

The results of the rail analysis are presented in Table H-2. There could be about 5.77 total fatalities associated with the national 1990 census-based results extrapolated to the year 2035. There could be also about 5.84 total fatalities associated with the national 2000 census-based results extrapolated to the year 2035.

The total impacts of the Nevada 1990 census-based results extrapolated to the year 2035 could be 1.18 fatalities. The total impacts of the Nevada 2000 census-based results extrapolated to the 2035 could be 1.18 fatalities.

This analysis shows that extrapolating from the 1990 or 2000 census population data yields similar results.

H.6 References

157136	Johnson and Michelhaugh	Johnson, P.E.; Michelhaugh, R.D. Transportation Routing Analysis Geographic Information System (WebTRAGIS) User's Manual. ORNL/TM-2000/86. Oak Ridge, Tennessee: Oak Ridge National Laboratory.
104780	Johnson et al. 1993a	Johnson, P.E.; Joy, D.S.; Clarke, D.B.; and Jacobi, J.M. 1993a. HIGHWAY 3.1—An Enhanced Highway Routing Model: Program Description, Methodology, and Revised User's Manual. ORNL/TM-12124. D00000000-02268-2003-20012 REV 1. Oak Ridge, Tennessee: Oak Ridge National Laboratory. ACC: MOV.19960711.0024.
104781	Johnson et al. 1993b	Johnson, P.E.; Joy, D.S.; Clarke, D.B.; and Jacobi, J.M. 1993b. INTERLINE 5.0—An Expanded Railroad Routing Model: Program Description, Methodology, and Revised User's Manual. ORNL/TM-12090. D00000000-02268-2002-20015 REV 1. Oak Ridge, Tennessee: Oak Ridge National Laboratory. ACC: MOV.19960711.0014.

Table H-1. Comparison of 1990 and 2000 Census-Based Results for Truck Transportation to the Repository for the Proposed Action.

Impact	1990 Census-Based Results[a,b]	2000 Census-Based Results[a,b]
National Impacts		
Public Incident Free Radiation Dose (person-rem)	5,010	5,520
Occupational Incident Free Radiation Dose (person-rem)	14,100	14,100
Radiological Accident Risk (person-rem)	0.463	0.548
Public Incident Free LCFs	2.5	2.8
Occupational Incident Free LCFs	5.6	5.6
Pollution-Related Fatalities	0.93	1.1
Radiological Accident Risk LCFs	2.3E-4	2.7E-4
Traffic Fatalities	4.5	4.5
Total Fatalities	13.54	13.99
Nevada Impacts		
Public Incident Free Radiation Dose (person-rem)	340	329
Occupational Incident Free Radiation Dose (person-rem)	1,860	1,860
Radiological Accident Risk (person-rem)	0.0521	0.0466
Public Incident Free LCFs	0.17	0.16
Occupational Incident Free LCFs	0.75	0.75
Pollution-Related Fatalities	0.086	0.077
Radiological Accident Risk LCFs	2.6E-5	2.3E-5
Traffic Fatalities	0.47	0.47
Total Fatalities	1.47	1.46

a. Extrapolated to the year 2035.

b. Does not include rail shipments in the Mostly Truck Scenario.

Table H-2. Comparison of 1990 and 2000 Census-Based Results for Rail Transportation to the Repository for the Proposed Action.

Impact	1990 Census-Based Results[a,b]	2000 Census-Based Results[a,b]
National Impacts		
Public Incident Free Radiation Dose (person-rem)	1,240	1,340
Occupational Incident Free Radiation Dose (person-rem)	3,940	3,960
Radiological Accident Risk (person-rem)	0.862	0.893
Public Incident Free LCFs	0.62	0.67
Occupational Incident Free LCFs	1.6	1.6
Pollution-Related Fatalities	0.56	0.58
Radiological Accident Risk LCFs	4.3E-4	4.5E-4
Traffic Fatalities	3.0	3.0
Total Fatalities	5.77	5.84
Nevada Impacts		
Public Incident Free Radiation Dose (person-rem)	72.1	85.1
Occupational Incident Free Radiation Dose (person-rem)	1,330	1,330
Radiological Accident Risk (person-rem)	0.00912	0.00527
Public Incident Free LCFs	0.036	0.043
Occupational Incident Free LCFs	0.53	0.53
Pollution-Related Fatalities	0.015	0.0084
Radiological Accident Risk LCFs	4.6E-6	2.6E-6
Traffic Fatalities	0.59	0.59
Total Fatalities	1.18	1.18

a. Extrapolated to the year 2035.

b. All results are for the Caliente heavy-haul truck Nevada implementing alternative. Does not include truck shipments in the Mostly Rail Scenario.

Appendix I
Development Plan

JASON TECHNOLOGIES CORPORATION
DEVELOPMENT PLAN CHECKLIST

Document Identifier: CAL-HSS-ND-000003 | Rev. No.: 0

Technical Product Title: Transportation Health and Safety Calculation/Analysis Documentation in Support of the Final EIS for the Yucca Mountain Repository

Requirement	Applicable to This Product? (Y/N)	If YES in Previous Column, Describe Satisfaction of Requirement (Add Attachments and References if Necessary). If NO in Previous Column, Justify
(1) Define work scope and objectives, and list the primary tasks involved.	Y	To document the methods and references used to estimate the transportation impacts presented in the *Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada*. Specifically, this calculation package addresses radiological and non-radiological transportation and transportation-related activities. For each impact category analyzed, this document discusses the following: • methods, • assumptions, • use of computer software and models, and • the calculations/analysis and results.
(2) Identify scientific approaches or technical methods used to collect, analyze, or study results of the work.	Y	Methods used are: estimates of shipment numbers, estimates of population projections, risk analysis of transportation of spent nuclear fuel (SNF) by various transportation modes, calculation of route segment lengths and population densities, calculation of accident probabilities and conditional severity and release probabilities, calculation of radiation doses and health effects, and of non-radiological health effects.
(3) Identify applicable standards and criteria.	N	None applicable.
(4) Identify and/or create implementing documents (procedures) required to perform the work.	Y	The Transportation Calculation package will be developed in accordance to Jason Procedure YP-014.
(5) Identify resources (and the functional requirements of the resources) required to perform the work.	Y	Approximately 30,000 hours of analyst and supervisor time, Internet connection, Microsoft ACCESS database software, Excel software for calculating on spreadsheets, remote UNIX systems, a terminal emulator, and Microsoft Word software for word processing.
(6) Identify records required to verify completion of the work and results obtained.	Y	Results of the work are presented in Chapter 6 and Appendix J of the EIS.
(7) Identify QA program applicability including QA/QC verification of work. If necessary, perform a QAP-2-0, *Conduct of Activities*, evaluation.	N	Jason QA (peer review) is required. This work is not at the level of Q list. (QA:N/A. as denoted in header).
(8) Identify prerequisites, special controls, environmental conditions, processes, or skills.	N	Since this work involves documentation of results, none of these are applicable.
(9) Identify computer software required to perform the work and the qualification status of the software.	Y	Codes run remotely include INTERLINE, HIGHWAY, CALVIN, RADTRAN. All have QA documentation. Additional commercial software includes Microsoft ACCESS, RISKIND, NetTerm, WS_FTP, Microsoft Word and Microsoft Excel. No further qualification is required.

(10) Coordinate planning with other analysts providing input or using results. Document concurrence, if appropriate. (Develop an Interface Control Document).	Y	Input will be taken from best available data and from other calculation packages. Documentation refrences will be provided. No ICD is required.
(11) Identify accuracy, precision, and representativeness requirements for, and limitations on, the results.	Y	The accuracy, precision and representation requirements of the calculation package contents will be derived from best available data. An internal peer review program is such that each section is reviewed by a qualified independent reviewer who is a member of the team.

Originator: (Printed Name) Ruth Weiner	Signature: Ruth F Weiner	Date: 1/15/02
Responsible Manager: (Printed Name) Diane E. Morton	Signature:	Date

JASON TECHNOLOGIES CORPORATION
DEVELOPMENT PLAN CHECKLIST

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(3) Identify applicable standards and criteria.	N	None applicable.
(4) Identify and/or create implementing documents (procedures) required to perform the work.	Y	The Transportation Calculation package will be developed in accordance to Jason Procedure YP-014.
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(10) Coordinate planning with other analysts providing input or using results. Document concurrence, if appropriate. (Develop an Interface Control Document).	Y	Input will be taken from best available data and from other calculation packages. Documentation refrences will be provided. No ICD is required.
(11) Identify accuracy, precision, and representativeness requirements for, and limitations on, the results.	Y	The accuracy, precision and representation requirements of the calculation package contents will be derived from best available data. An internal peer review program is such that each section is reviewed by a qualified independent reviewer who is a member of the team.

Originator: (Printed Name) Ruth Weiner	Signature: Electronic Signature	Date: 01-16-02
Responsible Manager: (Printed Name) Diane E. Morton	Signature: Diane E. Morton	Date 1/17/02