Emergency Response to a Nuclear Waste Shipment Accident, Inyo County

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Abstract: If a high-level waste repository opens at Yucca Mountain, a large amount of nuclear waste is expected to pass through Inyo County, California. Given the size of the first response jurisdiction, the 'round-the-clock' needs, and relatively small staffing pool that exists, just the everyday transport of these shipments will press on the resources available. In the event that a radioactive release occurs due to a severe accident, a quick and effective response is needed to ensure public safety. Working with Inyo County, members of Radioactive Waste Management Associates have developed a method using a Geographic Information System (GIS) to determine the likely locations of severe accidents along proposed routes. This presentation will describe the layers that were used and discuss related emergency response topics. In the end, a comprehensive assessment of the likely routes, risks, and possible regulatory and public safety responses to the potential shipment of nuclear waste will be carried out.

INTRODUCTION

This report discusses the impacts of the potential Spent Nuclear Fuel (SNF) and High-level radioactive waste (HLW) shipments through Inyo County, California, en route to the proposed repository at Yucca Mountain, Nevada. If this facility is licensed by the Nuclear Regulatory Commission (NRC) and then becomes operational, a large percentage of the waste bound for Yucca Mountain may traverse Inyo County. Depending on the route chosen, Inyo County may be among the most impacted communities in the United States because of its proximity to the destination for the national shipment campaign. This report fills a key need for Inyo County by describing the circumstances under which the county may become an important thoroughfare for these materials.

If a high-level waste repository opens at Yucca Mountain, a number of truck shipments of nuclear waste are expected to pass through Inyo County. These shipments of nuclear waste would lead to a radiation dose to the public even if the transport is incident-free, because no shielding material can reduce direct gamma radiation by 100%. As a result, residents, drivers, pedestrians and workers will get a radiation dose, which depends on the recipient's proximity and duration to the passing radiation source.

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This nuclear waste shipment campaign will also increase the associated accident risk on the study roads. Possible accident scenarios range from high probability and low consequence to low probability and high consequence. In case of a severe accident involving a nuclear shipment, the dose to individuals and the population would be much higher. In contrast to incident-free transportation, such an accident would cause both acute and long-term exposures, because radioactive particulates would be dispersed in the environment and continue to lead to radiation exposures. A severe transportation accident leading to a release of radioactive particulates is possible and credible. It could be caused by high impact, long duration fire or sabotage. Such an accident would lead to high radiation exposures due to inhalation of particulates (acute dose) and ground shine, i.e. direct gamma radiation from deposited radionuclides (long-term dose). Additional exposure to radiation would arise from ingestion of contaminated food, water and soil, even though the dose due from the ingestion pathway is very small in comparison to the inhalation and ground shine pathways.

The original report provided to Inyo County estimated the radiological and non-radiological risks associated with the forecasted shipment scenarios for each of the three alternative routes identified by Inyo County. The radiological risks for routine, incident-free shipments and risk arising from accidents involving release of radioactive materials were determined for a maximally exposed individual (MEI) and to the population.

The general methodology of this paper is given as follows:

1. Provide a description of the likely routes through Inyo County
2. Determine the range of possible accident scenarios from high probability and low consequence to low probability and high consequence.
3. Determine the likely locations of severe accidents along proposed routes.
4. Discuss the impacts of a severe accident occurring in Shoshone, CA involving a release of radioactive material including the acute dose to the population and an estimate of the economic consequences.
5. Discuss the possible regulatory and public safety responses to the potential shipment of nuclear waste, as well as related emergency response topics.

STUDY AREA AND CONTEXT

Inyo County

Inyo County is located in east-central California, on the east side of the Sierra Nevada Mountain Range. According to the US Census, the total population in 2000 was 17,945. The County contains both the highest peak in the lower 48 states (Mt. Whitney) as well as the lowest point in the United States (Death Valley). Inyo County measures 26,488 km^2 (10,227 mi^2) in area, making it the second largest county in California. The population density of Inyo County is 0.683 people per km^2. One of the many attractions of the County is Death Valley National Park. According to the National Park Service, 764,820 people visited Death Valley National Park in 2004. The total visitor population is separated by the eight entrances to the park.

Description of Routes

There are three variations on the highway routes through Inyo County: Route 1, Route 2, and Route 3 (Figure 1). Each route begins at the intersection of Interstate 15 and CA-127 in Baker, CA. From this point the routes take different segments to reach Highway 95 in Nevada. The County has no rail routes to Yucca Mountain.

Route 1 (Segments 1 & 2): Highway 127 is the first route, extending from Interstate 15 at Baker, CA to Shoshone, CA (Segment 1). The route continues on CA 127 to the Nevada state border where it becomes NV 373 until it reaches Highway 95 (Segment 2). This is the most direct route from Interstate 15 to Yucca Mountain measuring 173.35 km in length.

Route 2 (Segments 1 & 3): The second route also begins in Baker, CA and travels north on CA 127 to Shoshone, CA (Segment 1). Approximately 27 miles north of Shoshone is Death Valley Junction. This area has been identified as a flood-prone area. If flooding conditions occur here, shipments would be prevented from traveling north on CA 127 to Yucca Mountain. Instead, the shipments would turn east on CA 178 to the Nevada border, travel through the city of Pahrump on NV 372 to NV 160, until they reach Highway 95 (Segment 3). The total distance traveled on Route 2 is 178.95 km.

Route 3 (Segments 1 & 4): The final alternative, like the others, begins by traveling north on CA 127 from Baker, CA to Shoshone, CA (Segment 1). Conditions that prevent trucks from entering Nevada on CA 127, such as flooding, would cause shipments to leave the highway and travel north on CA 190. This route passes through Death Valley National Park and would eventually lead to Highway 95 in Beatty on NV 374 (Segment 3). The total distance traveled is 254.15 km, making it the longest of the study routes.

Expected Number of Shipments

The Final Environmental Impact Statement (FEIS) for Yucca Mountain estimates that under the Proposed Action for the mostly-truck scenario a total of 53,086 waste shipments would be made to Yucca Mountain, which calls for shipments of 70,000 metric tons of heavy metal (MTHM) including 63,000 MTHM of commercial spent nuclear fuel (CSNF) to the facility from 2010 through 2033. If the expansion of Yucca Mountain (known as Modules I and II) is approved, the FEIS estimates that the number of shipments to increase to 108,844 between the years 2010 and 2048.

It should be noted that the estimates used in this study are the minimal number of shipments that will be necessary to transport all of the SNF from reactor sites. The nation's inventory of CSNF is expected to exceed the 63,000 MTHM estimate used for this analysis. Currently there is a legislative cap on the amount of nuclear waste Yucca Mountain can contain. However, a Senate bill S.2589 will remove that cap, allowing

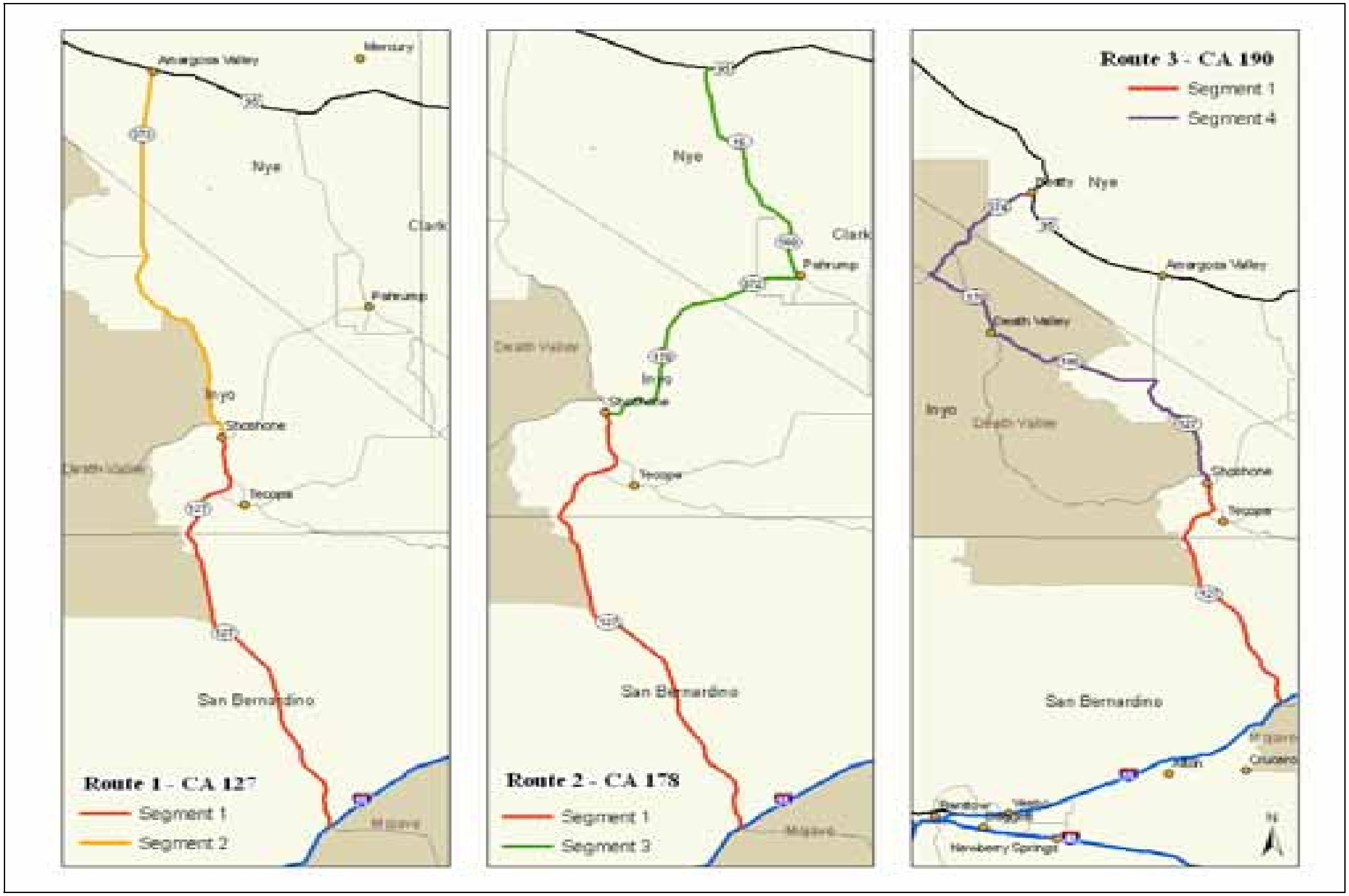

Figure 1. Three shipment variations through Inyo County, California

higher amounts of nuclear waste to be stored at the repository. Many of the utilities operating nuclear reactors have already applied for license renewals and others intend to do so. License renewals are for an additional 20-year operational period. These renewals would increase the total amount of CSNF, increasing the number of shipments needed, and thus increasing the expected dose.

The most variable estimate concerns the number of shipments expected to travel through Inyo County en route to Yucca Mountain. Estimates will vary depending on the expected number of truck vs. rail shipments, the number of shipments expected to take one route rather than another alternative, the number of reactor license renewals, etc. Under the first two transportation scenarios it is assumed that the shipments will use the Interstate Highway System and that none of the truck shipments will pass through Inyo County. Therefore this scenario will not be analyzed in this study. Under the Southern Alternative scenarios, all of the truck shipments pass through Inyo County. Finally, under the North – South routing scenario, 27,750 shipments will traverse Inyo County for the Proposed Action while Modules 1 and 2 calls for 55,112 shipments through the County (Table 1).

Table 1. Expected number of shipments through Inyo County

	N/S Alternative	**Southern Alternative**
Proposed Action	27,750	52,367
Modules I & II	55,112	105,985

METHODOLOGY

Collective Accident Risk

To estimate the expected number of accidents of various severities along study roads resulting from the shipping campaign, the RADTRAN 5 computer code[1] is used. The program considers a range of possible accident scenarios and their related probabilities, including low-probability accident scenarios that have high consequences and high-probability accident scenarios that have low consequences. For this study, six accident categories were used that were taken from the Yucca Mountain FEIS. Table 2 shows the most important parameters that were used as inputs to RADTRAN 5. For parameters that we did not specify here, RADTRAN default values are used.

Accident Locations

Together with Inyo County, CALTRANS, Nevada Department of Transportation (DOT), and the California Highway Patrol, we investigated potentially troublesome areas along the study routes traversing Inyo, San Bernardino, and Nye Counties. A wide-range of

[1] Neuhauser, Kanipe, and Weiner, 2000.

Table 2. Input parameters used for RADTRAN for collective accident risk

Variable	Value	Comments
Cask Dimensions (m)	Length: 4.4 Radius: 0.508	YM FEIS
Truck Size (m)	Length: 21	YM FEIS
Crew	Size: 2 Distance: 6 m View: 1.16 m	YM FEIS
Distance traveled (km)	*Segment 1* Rural: 90.28 Suburban: 0.97 *Segment 2* Rural: 82.1 *Segment 3* Rural: 74.2 Suburban: 13.5 *Segment 4* Rural: 162.9	WebTRAGIS Segments are shown in Figure 1
1-way traffic density (vehicles/hour)	*Segment 1* Rural: 41.2 Suburban: 54.9 *Segment 2* Rural: 42 *Segment 3* Rural: 48.6 Suburban: 75.2 *Segment 4* Rural: 60.7	Based on 17-hour day, average of traffic density on study roads in both directions AADT was available in 2000 – 2004 for CA study roads and 1995 – 2004 for NV study roads Segments are shown in Figure 1
Accident rate (accidents/veh-km)	Segment 1 Rural: 7.43E-07 Suburban: 7.43E-07 Segment 2 Rural: 4.88E-07 Segment 3 Rural: 4.48E-07 Suburban: 1.08E-06 Segment 4 Rural: 4.35E-07	Accident rates obtained from CALTRANS and Nevada DOT Segments are shown in Figure 1
Number of stops	1	Assumed stop for 20 minutes for refueling
Average truck speed (mph)	Rural: 45 (72.4 km/h) Suburban: 25 (40.2 km/h)	Average truck speed on study roads
Accident Probability Fraction	Category 1: 9.94E-01 Category 2: 4.05E-05 Category 3: 3.82E-03 Category 4: 1.80E-03 Category 5: 1.55E-05 Category 6: 9.84E-06	YM FEIS

data including but not limited to accident history, traffic counts, highway speeds, and road grade were used to determine specific accident 'hotspots'. The chosen locations provide a range of potentially severe accident scenarios, from the higher-density areas in Shoshone or Pahrump to the relatively remote areas along CA 127.

Radiological Release from Severe Accident

The decision to perform a consequence assessment for an accident occurring along the study routes was made in order to provide a hypothetical exercise with which to estimate damages and provide guidance for emergency responders. Obviously, it is impossible to predict the precise location of an accident, its severity, and the meteorological conditions at the time of the accident. However, it is instructive to provide a hypothetical scenario as a representative possibility of what could happen if there were a severe accident in Inyo County. In a "severe accident", the cask is breached open upon impact or a long-duration fire, and radionuclides are released to the environment.

In this section, we calculate the acute dose to the population (in person-rem) due to a severe accident involving a nuclear transportation truck cask. The RISKIND[2] computer program is used to calculate the acute dose to the population. In addition to RISKIND, the computer program HotSpot[3] was used to obtain contaminant plumes for later inclusion onto a map. HotSpot was developed at Lawrence Livermore and is used to estimate levels of radioactive contamination following an accident.

Although the population densities are similar in Shoshone to that of its rural surroundings, we differentiate between the two. In Figure 7, the blue outlined area encloses the town boundary of Shoshone. Using population data from the 2000 US Census, we arrive at a population density in Shoshone of 0.7 people per km^2 (Table 3). The city of Bishop and its surroundings contain nearly 63% of Inyo County's population (11,290 people). Therefore, if we exclude the population of Shoshone and the Bishop region, we get a more accurate population density for the area surrounding Shoshone in Inyo County. The population density of Inyo County, excluding Shoshone and Bishop, is 0.254 people per km^2.

Table 3. Population density of Shoshone, CA

Region	Pop.2000	Area (km^2)	Dens.2000 (p/km^2)
Inyo County	17,945	26,262.48	0.683
Shoshone	52	74.4	0.7
Bishop Region	11,290	171.82	65.7
Inyo Co. excl. Shoshone and Bishop Region	6,603	26,016.26	0.254

2 USDOE, 1995.

3 "Hotspot Health Physics Code, Version 1.06." Lawrence Livermore National Laboratory. Steven G. Homann, contact.

Table 4 shows the parameters that were used as inputs for RISKIND and HotSpot to determine the radiological release from an accident occurring in the town of Shoshone, CA. The specific location chosen for the accident was near the gas station located on CA 127 just north of the CA 127 and CA 178 intersection. Most values were taken from the Yucca Mountain FEIS, Chapter 6 and Appendices A and J. To estimate the release fractions to be used in this study, we take the results from the Modal Study[4] accidents corresponding to severity Category 5 as used in the Yucca Mountain FEIS, correcting for the additional cesium believed to be in the fuel-cladding gap. Meteorological conditions were taken from the nearest stations with historical records. For parameters that we did not specify here, we used default values.

Also using the contamination plumes developed in HotSpot, we were able to make an estimate of the cleanup, decontamination, and relocation costs associated with the spent fuel shipping accidents hypothesized in this study. In order to do this the dollar/area costs estimated by Chanin and Murfin[5] are multiplied by the area of contamination for each of the three contamination areas: light, moderate, and heavy.

Table 4. Inputs into RISKIND and HotSpot

Parameter	Value	Comments
RISKIND:		
Acute exposure	24 h	Estimated evacuation time
Long-term exposure	1 and 50 y	Exposure range
Shielding	None	Default
Cask dimensions	length 4.4 m radius 0.508 m	YM FEIS
Burnup	50,000 MWD/MTU	YM FEIS
Cooling time	15 y	YM FEIS
Total uranium in cask	1.696 MT	YM FEIS; 4 assemblies of 424 kg
Cask cavity surface area	39 m2	Default
Crud surface activity	140 micCi/m2	From YM FEIS
Mixing height	400-1600 m	Default
Temperature	283 K	Default
Anemometer height	10 m	Default
Rainfall	None	Default
Release height	1 m	Default
Release fractions:		
Particulates	0.000002	Modal Study
Ru	0.000048	Modal Study

[4] Fischer et al, 1987.
[5] Chanin, DI and WB Murfin, 1996.

Cs	0.0066	Value form Mod.St., multiplied by 33
I	0.0043	Modal Study
Gas	0.39	Modal Study
Heat release	500 ca/s	Default for accident without heavy fire
Parameter	**Value**	**Comments**
HotSpot:		
Dispersion model	General plume	
Released radionuclides (Ci)	0.016 H-3; 0.0024 Fe-55; 7.82 Co-60; 0.017 Ni-63; 2,780 Kr-85; 2.5 Sr-90; 2.5 Y-90; 0.016 Sb-125; 0.004 Te-125M; 21.8 Cs-134; 1,210 Cs-137; 3.48 Ba-137M; 0.081 Pm-147; 0.017 Sm-151; 0.18 Eu-154; 0.05 Eu-155; 0.22 Pu-238; 0.015 Pu-239; 0.025 Pu-240; 2.68 Pu-241; 0.1 Am-241; 0.15 Cm-244	Output from RISKIND
Deposition velocity	1 cm/s	Output from RISKIND
Wind speed	2.9 m/s	Average wind speed
Wind direction	NW	Dominant direction 1984 – 1992
Stability class	D	Most frequent stability class

RESULTS

Collective Accident Risk

There will be an increase in the number of accidents along study roads during the shipping campaign attributable to the increased truck traffic. This involves trucks transporting loaded casks to the repository as well as returning shipments of empty casks. The number of accidents expected on the three study routes under the Southern Alternative shipping scenario is shown in Table 5. The expected numbers of accidents under the North – South routing scenario are listed in Table 6. These two tables divide doses by route but also by accident severity. RADTRAN, like RISKIND calculates the number of expected accidents and fatalities from accidents per truck. We therefore multiply this number with 52,367 – 105,985 for the Southern Alternative Route and by 27,750 – 55,112 for the North – South Route.

Table 5. Number of expected accidents for the Southern Alternative scenario

	Southern Alternative					
	Proposed Action Scenario			*Modules I and II Scenario*		
Severity Category	**Route 1**	**Route 2**	**Route 3**	**Route 1**	**Route 2**	**Route 3**
1	1.12E+01	1.20E+01	1.44E+01	2.27E+01	2.44E+01	2.91E+01
2	4.57E-04	4.90E-04	5.87E-04	9.24E-04	9.92E-04	1.19E-03

3	4.32E-02	4.62E-02	5.55E-02	8.73E-02	9.36E-02	1.12E-01
4	2.04E-02	2.18E-02	2.61E-02	4.12E-02	4.42E-02	5.29E-02
5	1.75E-04	1.88E-04	2.25E-04	3.55E-04	3.80E-04	4.56E-04
6	1.11E-04	1.19E-04	1.42E-04	2.25E-04	2.41E-04	2.88E-04

Table 6. Number of expected accidents for the North – South routing scenario

	North – South Routing					
	Proposed Action Scenario			*Modules I and II Scenario*		
Severity Category	**Route 1**	**Route 2**	**Route 3**	**Route 1**	**Route 2**	**Route 3**
1	5.94E+00	6.38E+00	7.63E+00	1.18E+01	1.27E+01	1.52E+01
2	2.41E-04	2.60E-04	3.11E-04	4.81E-04	5.16E-04	6.17E-04
3	2.29E-02	2.45E-02	2.94E-02	4.54E-02	4.87E-02	5.84E-02
4	1.08E-02	1.16E-02	1.38E-02	2.14E-02	2.30E-02	2.75E-02
5	9.30E-05	9.96E-05	1.19E-04	1.85E-04	1.98E-04	2.37E-04
6	5.88E-05	6.30E-05	7.55E-05	1.17E-04	1.25E-04	1.50E-04

The expected risk value of early fatality and morbidity due to accidents from the shipment of nuclear waste on the study roads is calculated using the RADTRAN software (Table 7). We multiply this number with 52,367 – 105,985 for the Southern Alternative Route and by 27,750 – 55,112 for the North – South Route.

Table 7. Expected fatality and morbidity risk for Southern and North – South Routing scenarios

	Southern Alternative					
	Proposed Action Scenario			*Modules I and II Scenario*		
	Route 1	**Route 2**	**Route 3**	**Route 1**	**Route 2**	**Route 3**
Fatality	1.72E-07	3.24E-06	4.10E-07	7.19E-07	6.55E-06	8.30E-07
Morbidity	8.17E-07	7.44E-06	9.43E-07	1.65E-06	1.50E-05	1.91E-06

	North – South Routing Alternative					
	Modules I and II scenario			*Modules I and II Scenario*		
	Route 1	**Route 2**	**Route 3**	**Route 1**	**Route 2**	**Route 3**
Fatality	1.88E-07	1.71E-06	2.17E-07	3.74E-07	3.41E-06	4.32E-07
Morbidity	4.33E-07	3.94E-06	5.00E-07	8.60E-07	7.83E-06	9.92E-07

Accident Locations

Overall accident rates are expected to increase along the study roads due to increased truck traffic of SNF and HLW. The majority of these accidents will be non-release incidents, thus increasing the overall non-radiological risk. However, there are several troublesome areas along the study routes traversing Inyo, San Bernardino, and Nye Counties that could potentially lead to a severe accident.

Keeping in mind that the chosen locations are intended to be representative, and that this study is in no way predicting the location of accidents, we investigate the following scenarios which can also be seen in Figure 6:

A. There are a series of curves along CA 127 that are thought to be potential accident areas. The major concern at these locations is severe curves that can cause “curve accidents”. Accidents are likely to occur when high speeds and less attentive driving are involved. Due to the relatively remote nature of these locations, trucks can be expected to travel at fairly high speeds, giving the possibility of a severe impact scenario. The average speeds along this roadway are between 55 – 60 miles per hour. However, trucks can approach 70 miles per hour along the barren stretches of CA 127. The short distance and absence of dividers between the north- and southbound lanes creates the possibility for high-speed, head-on collisions. Listed blow are problematic areas along the study roads:

   - The first location is on CA 127 approximately 1.5 – 2 miles north of Shoshone near mile post 16. This area is known as ‘The Milky Way’ because milk trucks are frequently seen on the route (Figure 6). There is a series of curves along this stretch where a great deal of accidents involving larger trucks has occurred in the past. It is a major concern because the potential threat is to trucks traveling northbound, thus loaded with waste traveling to the Yucca Mountain facility. This area has also been flagged as a ‘drop zone’ for communication. Cell reception and other forms of communication are limited, thus increasing the response time for a severe accident.

   - There is a sharp curve located on CA 127 in Death Valley Junction. Once again, this area is a potential threat to loaded trucks traveling northbound. This curve is also located in close proximity to people living in the town as well as any tourist activity.

   - One other accident hotspot is located on CA 127 near Eagle Mountain. The exact location can be seen in the first map inset of Figure 6. This area contains two potentially dangerous curves that could lead to a severe accident.

B. There are several low-lying areas along CA 127 that have been designated by the Federal Emergency Management Agency (FEMA) as floodplain boundaries. The floodplain boundaries can be seen in Figure 6 as a gray-hatched area. These areas are prone to flooding or flash flooding which can cause washouts. In the past, flash flooding has caused road closures along CA 127 and CA 190 in Inyo County. One example of this is the town of Death Valley Junction which has been noted as an issue area. This type of natural hazard can leave truck shipments stranded, disrupt service, or in a worse case scenario cause a severe accident.

C. Steep grades along the transportation corridor can pose problems to heavy trucks carrying nuclear waste north to the Yucca Mountain facility. The combination of heavy trucks and severe highway downgrades could cause brake failures and lead to a potentially severe accident. Also, steep grades can pose problems to trucks returning from Yucca Mountain, traveling south on the study roads. A runaway truck, traveling at high speeds, could collide head-on with loaded trucks traveling northbound. Elevation profiles were created along the study roads to determine steep slopes (Figures 2 & 3). It is important to note that in these figures, a drastic, out-of-place spike in elevation is caused by mapping error. However, the larger spikes in elevation occurring over longer distances are representative of road conditions and are discussed in more detail.

- The elevation profile for CA 127 traveling north from Baker to Shoshone can be seen in Figure 2. From this we can see that after a severe rise in elevation from under 500 feet to over 2,000 feet in less than 10 miles, the road descends to nearly 1,250 feet in just a few miles. Also, the slope for trucks returning from Yucca Mountain, traveling south on CA 127 is severe between the 40 and 30 mile mark.

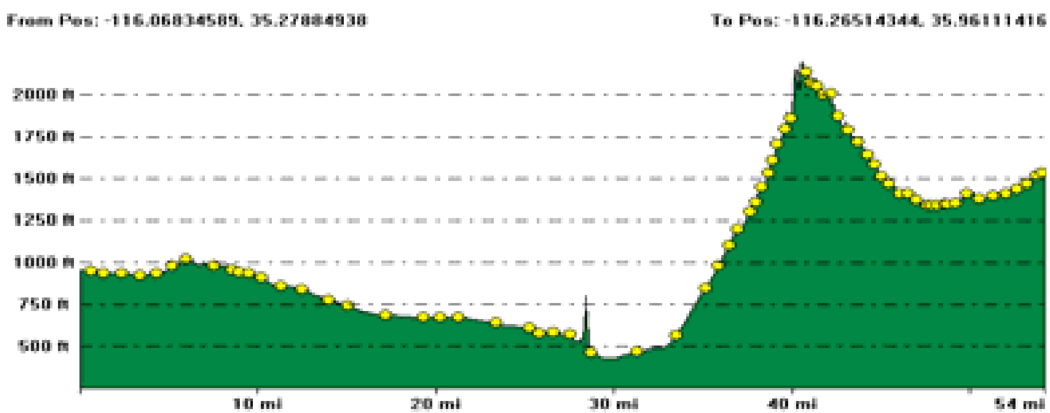

Figure 2. Path CA 127 traveling north from Baker to Shoshone

- A second profile can be seen in Figure 3 for CA 127 traveling south from Death Valley Junction to Shoshone. Once again, areas with steep grade (high slope) can pose a threat to trucks hauling nuclear waste. The areas of concern can be seen just before the 10 and 20 mile mark, and for the last 5 miles into Shoshone.

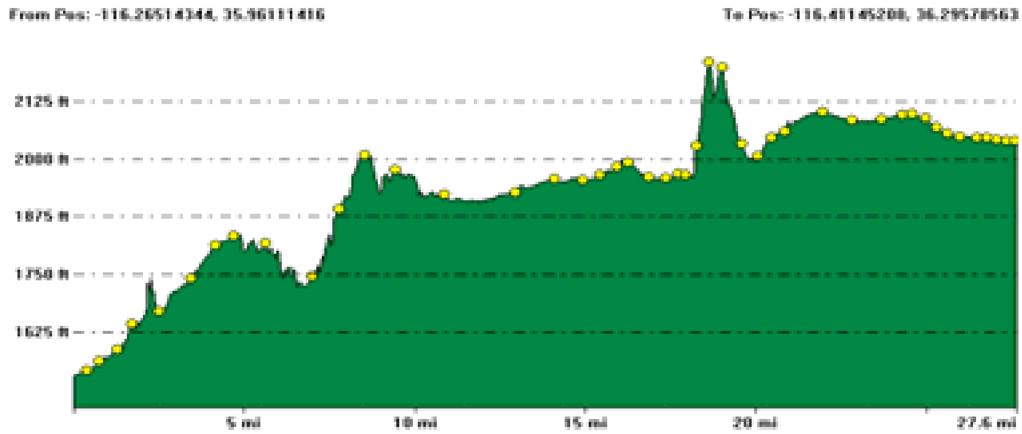

Figure 3. Path CA 127 traveling south from Death Valley Junction to Shoshone

D. Accident locations along the study routes between 1994 and 2005 were obtained from CALTRANS. The locations where accidents occurred were referenced to the study roads by mileage posts and can be seen in Figure 4 and as blue circles in the third map inset of Figure 6. In Figure 4 accidents are symbolized by the type of accident while Figure 6 categorizes accident by the number of individuals injured per accident. From this information areas with a high frequency of accidents were identified:

- The first example of this is on CA 127 in Inyo County, just north of the San Bernardino County border (Map Inset 3 – Figure 6). There have been numerous accidents recorded at this location.

- Another spot in Inyo County with a high accident rate is at the intersection of CA 127 and CA 178 (Figure 4). This location has also been identified as a low-lying area within the FEMA designated flood boundary.

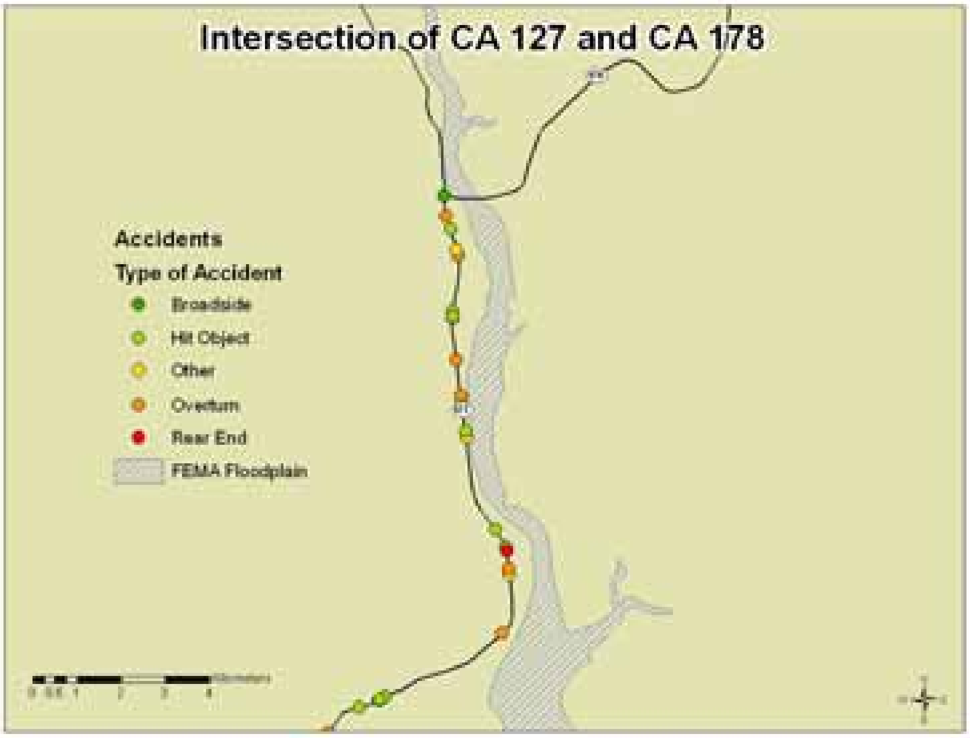

Figure 4. Types of accidents on CA 127

E. A long duration fire leading to the release of radioactive material is possible and could be caused by a collision with a truck hauling explosive material or a gas tanker. There have already been a large number of trucks identified on the transportation corridor. Some of these trucks contain hazardous materials including acids, caustics, and explosives. Also possible is an explosion at a gas station located adjacent to the corridor or with a truck filled with gasoline.

F. There can be a considerable amount of large, slow moving recreational vehicles and trailer combinations on CA 127 near the Dumont Dunes off-road vehicle recreational area (Figure 5, Figure 6). There are two ways of accessing the dunes. The Little Dunes staging and camping area is directly off CA 127. One mile north of this point, just off CA 127, is Dumont Road, a dirt road that leads to the main field of large dunes. The average speeds along this roadway are between 55 – 60 miles per hour. As mentioned before, due to the relatively remote nature of this location, trucks can be expected to travel at fairly high speeds. The risk these slow moving vehicles pose to shipments may be significant.

Figure 5. Dumont Dunes off-road recreational area

G. To compare the first accident locations (A) with that of a more densely populated area along the study roads, a possible accident in the town of Pahrump, Nevada was chosen (Map Insert 4 – Figure 6). This accident scenario is relevant to Inyo County because the city is situated along the state border. Outer portions of the city are located within Inyo County, leaving the possibility for Pahrump to expand into the County even further. If such an accident were to occur in Pahrump, citizens of Inyo County would be impacted by the direct radioactive release as well as by individuals evacuating from the accident area and the need for an emergency response from California. A severe accident is possible at the interchange of NV 372 and NV 160 in Pahrump, Nevada. More specifically, the scenario will involve a truck traveling on NV 372 going onto NV 160.

H. Lastly the threat of a sabotage or terrorist attack is credible. This event could occur at any point along the transportation routes, leading to a radioactive release.

The eight accident scenarios (A-H) described above can also be seen in Figure 6. The specific letters (A-H), representing the different scenarios, are placed in the exact locations where those conditions are present in the far left map of Figure 6. For example, the first map inset identifies a severe curve, labeled A, near Eagle Mountain on CA 127. Steep slopes can be seen in the second inset, labeled C. Accident frequency is labeled as D in the third inset, with blue circles representing where accidents have occurred on CA 127 in the past. Finally, the densely populated city of Pahrump can be seen in the last inset.

Acute Dose to Population from Severe Accident

The next step was to superimpose plume diagrams on the map of Shoshone and its surroundings to estimate the amount and extent of contamination and dose from a severe truck accident. Plumes for acute dose and ground deposition concentration were obtained from the HotSpot computer model and plotted in a Geographic Information System (GIS) which is shown in Figure 7.

The population dose (person-rem) is calculated by multiplying the average dose (rem) of a dose zone with the respective population (persons). The dose zones are the areas between two neighboring dose isopleths. The dose zone population is calculated from the population density and the surface of each dose zone. The isopleths of the six highest acute doses are completely inside of Shoshone, whereas the ones with acute doses below 1 rem are partially outside. By measuring the plumes on the map and applying basic geometric calculations of ellipse segments, we calculate the area of each dose zone inside and outside of Shoshone (Table 8).

For example, the second dose zone listed in Table 8 is the area between the 100 rem plume and the 50 rem plume. The average dose in this area is calculated as (100 + 50)/2 = 75 rem. We then multiply this number by the plume area (km^2) and the respective population density (persons/km^2) to determine the acute population dose (person-rem), [75 rem*0.002 km^2*0.7 p/km^2 (2000) = 0.105 person-rem]. This number represents the average dose to the population for the area between the 100 rem and 50 rem plumes.

Table 8. Acute dose to the population

Dose zone between isopleths	Av. Dose in dose zone (rem)	Surface of dose zone: Total (km^2)	Surface of dose zone: within Shos. (km^2)	Surface of dose zone: outside Shos. (km^2)	Acute population dose[a] 2000 (person-rem)
inside 100	>100	0.002	0.002	0	0.140
100 to 50	75	0.002	0.002	0	0.105
50 to 10	30	0.019	0.019	0	0.399
10 to 5	7.5	0.025	0.025	0	0.131
5 to 3	4	0.036	0.036	0	0.101
3 to 2	2.5	0.046	0.046	0	0.081
2 to 1	1.5	0.16	0.16	0	0.168
1 to 0.5	0.75	0.36	0.15	0.21	0.119
0.5 to 0.4	0.45	0.19	0.03	0.16	0.028
0.4 to 0.3	0.35	0.36	0.07	0.29	0.043
0.3 to 0.2	0.25	0.7	0.03	0.67	0.048
0.2 to 0.1	0.15	2.5	0.1	2.4	0.102
outside 0.1	<0.1	N/A	N/A	N/A	Omitted
Total					1.465

a: Dose calculated with population density estimates from 2000 US Census data

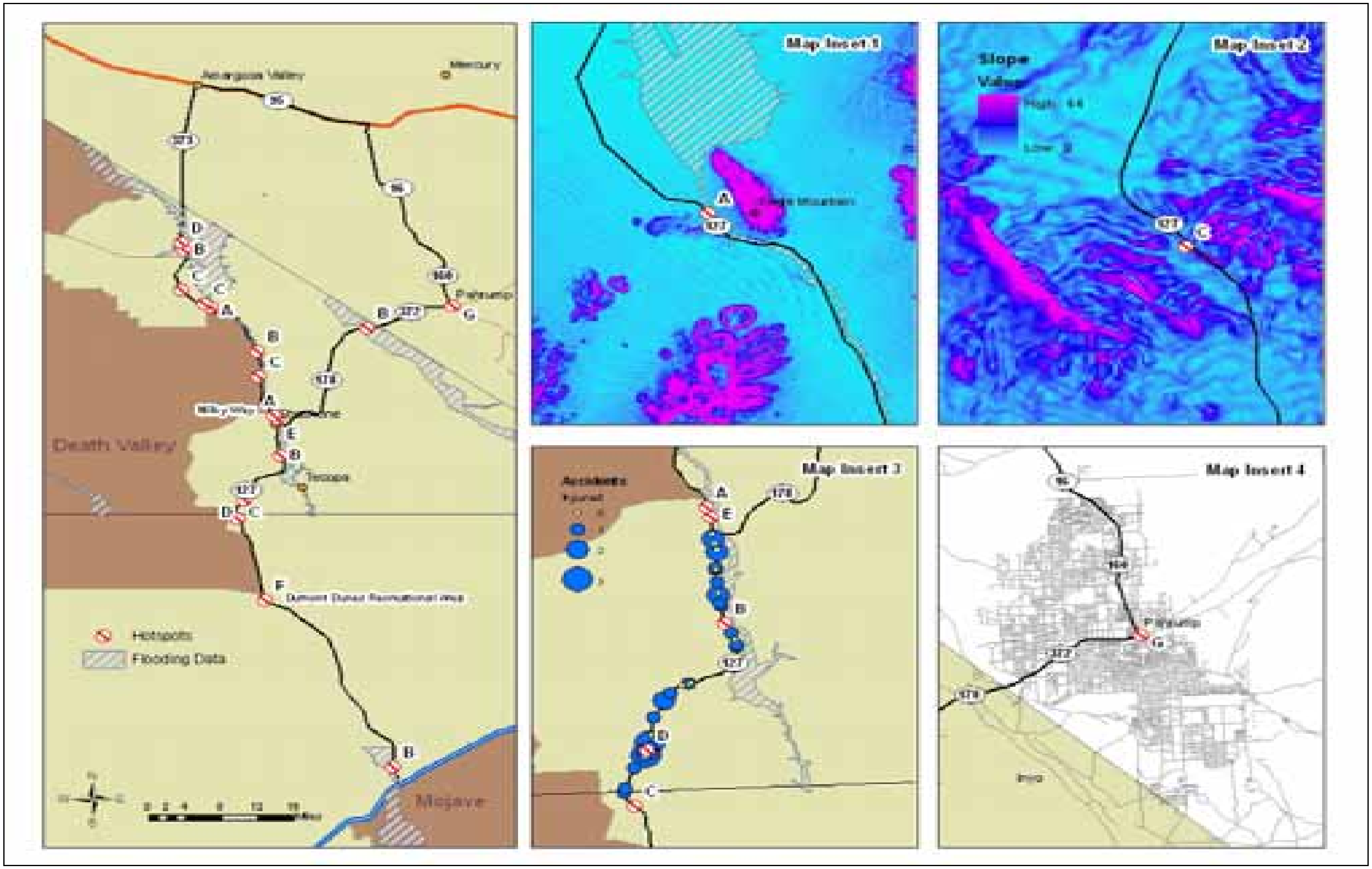

Figure 6. Potential accident scenarios along Inyo County study route

Estimated Economic Consequences of Decontamination and Cleanup

Table 9 presents the figures of the dollar and area estimates by Chanin and Murfin for each of the three contamination areas.

Table 9. Decontamination cost estimates: severe (Category 5) spent fuel accidents in Inyo County

	Heavily contaminated area	Moderately contaminated area	Lightly contaminated area	Total Cleanup Costs
Area (km^2)	0.004	0.005	0.039	
Cost/km^2	$394,604,748	$182,592,165	$128,263,609	$7,493,661

Table 9 shows that even without considering all of the economic impacts associated with the aftermath of a spent fuel transportation accident, the dollar figures would indicate a substantial consequence. These cleanup cost estimates would be significantly greater if meteorological conditions were different. For example, a higher wind speed or more stable atmospheric conditions would have contributed to a greater downwind dispersal and, consequently, greater contaminated areas.

DISCUSSION & CONCLUSION

A public safety assessment was completed as a separate task to the overall risk assessment project completed for Inyo County. The safety assessment targeted transportation related emergency response needs to assist Inyo County officials in determining emergency responder readiness for response to a transportation accident involving highly radioactive materials along various transportation pathways in the southeastern section of Inyo county. The particular agencies of relevance include the California Highway Patrol (CHP), Southern Inyo Fire Protection District (SIFPD), Nye County Sheriff’s Office, California Transportation Department, and United States Bureau of Land Management. Details about each agency, their coverage area in southern Inyo County, and their first responder functions were determined in that document.

The report concluded that emergency response agencies in southern Inyo County are hard pressed to provide the minimal level of basic services. A brief discussion of some of the issues concerning Inyo County is listed below:

- The Nye County, NV hazardous materials response team provides a 40 minute response time to Shoshone, CA after assembly of the team members.
- There are numerous dead spots in cell phone coverage throughout Inyo County.

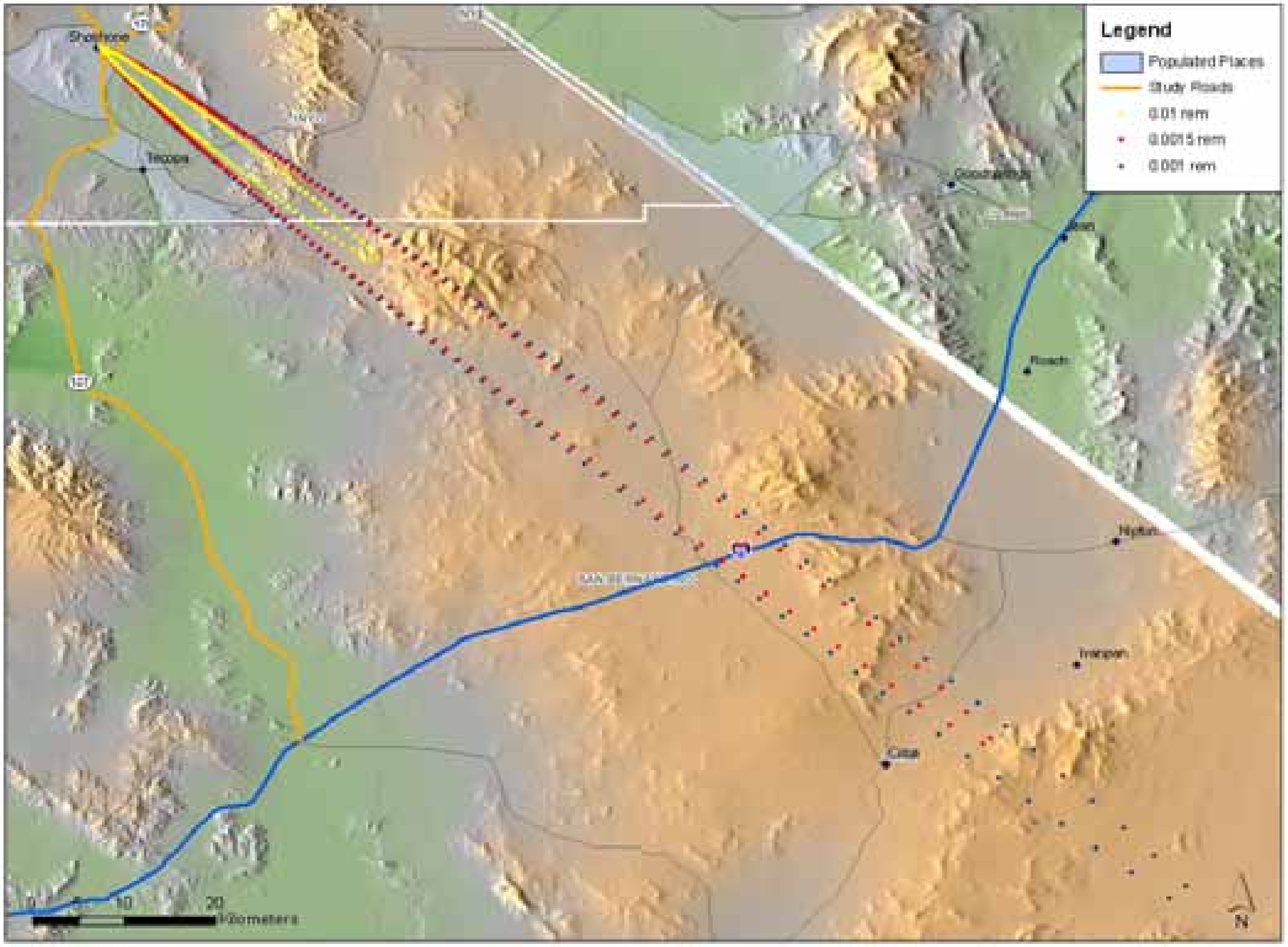

Figure 7. Acute dose isopleths in Inyo and San Bernardino Counties, CA: 0.01, 0.0015, and 0.001 rem

- The Inyo County Undersheriff notes that his officers have satellite phones but they do not always work in the area due to mountains which block southern horizon, thus they experience dead spots.
- Communication issues were considered a major safety issue for the CHP.
- The Inyo County Hazardous Materials Team is understaffed and ill equipped to handle a highly radioactive incident.
- The Hazardous Materials Team is not available 24-hours a day, 7 days a week and would have to be supplemented by outside agencies and support from other response assets.
- The use of outside contractors in the case of a radiological emergency would prove problematic since they would need to be transported to the scene.
- The SIFPD does have some familiarity with response to transportation incidents involving radioactive materials, but that training is out of date and needs to be updated, consistently trained for, and trained for by using real life simulations.

The combination of very large geographic area and minimal resources (personnel and equipment) makes it difficult for fire, law enforcement and emergency medical service agencies to meet current demands. These agencies cannot, and should not be expected to respond to the additional demands created by shipment of spent nuclear fuel and high level radioactive waste through the County to Yucca Mountain. Providing an adequate response to such a long term and large scale shipping program will require a different organizational structure and much more resources than currently are provided by the county, state and federal agencies.

This paper has shown that a severe transportation accident leading to a release of radioactive particulates is both possible and credible in Inyo County. Such an accident would lead to high radiation exposures due to inhaling and ingesting radioactive particulates and from groundshine. In the case of Inyo County, the worst-case accident scenario would involve several factors. The most severe consequences would occur in an area that is highly populated. An accident with steep grades, high speeds, and one that leads to a long duration fire could be the most severe. Also, conditions that increase response time would increase the overall severity of the accident. This includes accidents positioned in areas with limited or no communication, located in floodplain areas during storms, or in areas such as Death Valley National Park that may contain a high tourist population at the time of an event.

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