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June 22, 1999

Dr. Shirley Ann Jackson
Chairman
U.S. Nuclear Regulatory Commission
Washington, D. C. 20555-0001

Re: Nevada's Petition To Institute Rulemaking To Amend Regulations Governing Safeguards for Shipments of Spent Nuclear Fuel (SNF) Against Sabotage and Terrorism and To Initiate A Comprehensive Assessment

Dear Dr. Jackson:

Nevada Governor Kenny Guinn, on behalf of the people of the State of Nevada, has requested that this office file the attached Petition for rulemaking with the Commission. The Petition requests that the Commission initiate rulemaking to reexamine and strengthen its regulations governing safeguards for shipments of spent nuclear fuel against sabotage and terrorism in light of real world conditions.

It has been nearly two decades since the Commission reviewed its regulations designed to ensure the physical protection of spent nuclear fuel shipments. It is imperative that the Commission factor into its regulations the changing nature of threats posed by domestic terrorists, the increased availability of advanced weaponry and the greater vulnerability of larger shipping casks traveling across the country.

I respectfully urge the Commission to conduct the needed risk and consequence assessment of the existing safeguards and security regulations to determine if changes need to be made, publish new proposed rules for public comment, and ultimately to make the necessary modifications to the regulations. It is my sincere belief the current regulations expose the public across the country to unacceptable levels of risk from the transportation of highly radioactive materials. If you need additional information concerning this vital matter, please contact Marta Adams of my staff at (775)684-1237.

Cordially,

FRANKIE SUE DEL PAPA
Attorney General

FSDP:MA:nc

cc: Secretary, U.S. Nuclear Regulatory Commission
See attached list

cc Governors
Nevada Congressional Delegation
Attorneys General
U.S. Dept. of Energy
U.S. Dept. of Justice
U.S. Dept. of Transportation
Federal Emergency Management Agency

NUCLEAR TRANSPORTATION SECURITY AND SAFETY ISSUES
THE RISK OF TERRORISM AND SABOTAGE
AGAINST REPOSITORY SHIPMENTS

ATTACHMENT A

UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

Before

THE COMMISSIONERS

IN THE MATTER OF THE PETITION OF THE STATE OF NEVADA FOR THE AMENDMENT OF THE PHYSICAL PROTECTION REGULATIONS CONTAINED IN 10 C.F.R. 73 AS THEY RELATE TO THE SAFEGUARDS FOR SPENT NUCLEAR FUEL SHIPMENTS AGAINST TERRORISM AND SABOTAGE AND FOR THE INITIATION OF A COMPREHENSIVE ASSESSMENT OF THE CONSEQUENCES OF RADIOLOGICAL SABOTAGE)	**PETITION TO INSTITUTE RULEMAKING AND TO INITIATE A COMPREHENSIVE ASSESSMENT**

The State of Nevada (Petitioner) hereby respectfully requests and petitions the Nuclear Regulatory Commission (the Commission), pursuant to 5 U.S.C. § 553 and 10 C.F.R. 2.800-804, to exercise its rulemaking authority for the purpose of amending its regulations governing safeguards for shipments of spent nuclear fuel (SNF) against sabotage and terrorism. Specifically, Petitioner requests that the following regulations be amended:

(1) Design Basis Threat: "Radiological Sabotage" (10 C.F.R. 73.1(a)(1));

(2) Definitions: "Radiological Sabotage" (10 C.F.R. 73.2);

(3) General Requirements: Advance Approval of Routes (10 C.F.R. 73.37(b)(7));

(4) General Requirements: Planning and Scheduling (10 C.F.R. 73.37(b)(8));

(5) Shipments by Road (10 C.F.R. 73.37(c)); and

(6) Shipments by Rail (10 C.F.R. 73.37(d)).

Petitioner further respectfully requests and petitions the Commission, in support of the aforementioned rulemaking to amend safeguards regulations, to conduct a comprehensive assessment of the consequences of terrorist attacks that have the capability of radiological sabotage, including attacks against transportation infrastructure used during nuclear waste shipments, attacks involving capture of nuclear waste shipments and use of high energy explosives against a cask or casks, and direct attacks upon a nuclear waste shipping cask or casks using antitank missiles or other military weapons.

I. PROPOSED AMENDMENTS TO EXISTING REGULATIONS

Petitioner believes that the Commission should amend the current safeguards regulations in order to better deter, prevent, and mitigate the consequences of any attempted radiological sabotage against shipments of spent nuclear fuel (SNF). The Commission last publicly addressed the consequences of terrorist attacks on SNF shipments and the adequacy of its safeguards regulations in 1984. Petitioner is submitting an overview of the Commission's safeguards regulatory activities since 1979, and an analysis of the Commission's 1984 proposed rule. *See* Attachment A, Robert J. Halstead and David J. Ballard, *Nuclear Waste Transportation Security and Safety Issues: The Risk of Terrorism and Sabotage Against Repository Shipments* at 23-30 and Appendix B (October 1997).[1] Petitioner believes that a general strengthening of the regulations intended to safeguard SNF shipments is necessary because of new developments in two critical areas since 1984: (1) changes in the nature of the terrorist threat; and (2) increased vulnerability of shipping casks to terrorist attacks involving high-energy explosive devices.

A. *Reexamine the Design Basis Threat: "Radiological Sabotage"*

The Commission should reexamine the design basis threat used to design safeguards systems to protect shipments of SNF against acts of radiological sabotage. Current regulations require licensees to design safeguards systems which can protect shipments against attacks involving several well-trained and dedicated individuals, hand-held automatic weapons, a four-wheel drive land vehicle, and hand-carried equipment, including incapacitating agents and explosives. (10 C.F.R. 73.1(a)(1)(i)) The regulations also specify that the attackers may receive insider (employee) assistance (10 C.F.R. 73.1(a)(1)(ii)) and utilize a four-wheel drive land vehicle bomb (10 C.F.R. 73.1(a)(1)(iii)).

Petitioner requests that the Commission clarify the meaning of "hand-carried equipment" within the current design basis threat. Section 73.2 does not provide a definition of "hand-carried equipment." Petitioner believes that the definition of hand-carried equipment, in the hands of several

[1] Report prepared for Nevada Agency for Nuclear Projects, Carson City, Nevada

well-trained attackers, using a four-wheel drive vehicle to carry their equipment, includes (but is not limited to) the following explosive devices identified in Attachment A: (1) one or more large military demolition devices, such as the U.S. Army M3A1 shaped charge weighing 40 pounds; (2) a significant quantity (limited only by the carrying capacity of the vehicle) of commercial explosives packaged in crates, boxes, suitcases, or other hand-carried containers; and (3) numerous man-portable antitank weapon systems such as the Carl Gustav M2 recoilless gun (weight 15 kg), the Milan antitank missile (weight 32 kg), and the infantry version of the TOW 2 antitank missile (weight 116 kg with tripod launcher).

Petitioner further requests that the Commission, as part of a comprehensive reassessment of the consequences of terrorist attacks, consider amending the design basis threat to include use of explosive devices and other weapons larger than those commonly considered to be hand-carried or hand-held, and the use of vehicles other than four-wheel drive civilian land vehicles. Well-trained and dedicated adversaries could conceivably obtain and use military attack vehicles or military aircraft armed with bombs, missiles, or other powerful weapons. The possibility of attacks involving stolen or otherwise diverted military weapons systems should be given special consideration considering the number and nature of military installations in Nevada and along the transportation corridors to Nevada.

B. Reexamine the Definition of "Radiological Sabotage"

The Commission should reexamine the definition of "radiological sabotage." Current regulations define "radiological sabotage" as any deliberate act "which could directly or indirectly endanger the public health and safety by exposure to radiation." (10 C.F.R. 73.2) Petitioner requests that the Commission clarify the definition of "radiological sabotage." Petitioner believes that the wording "could directly or indirectly endanger" implies a judgment by the Commission regarding the consequences of the action, as opposed to the intentions of the individuals carrying out the action. Actions against SNF shipments which are intended to cause a loss of shielding or a release of radioactive materials should be included in the definition of "radiological sabotage" regardless of the success or failure of the action.

Petitioner also believes that the definition of "radiological sabotage" should be amended to explicitly include deliberate actions which cause, or are intended to cause economic damage or social disruption regardless of the extent to which public health and safety are actually endangered by exposure to radiation. An incident involving an intentional release of radioactive materials, especially in a heavily populated area, could cause widespread social disruption and substantial economic losses even if there were no immediate human casualties and few projected latent cancer fatalities. Local fears and anxieties would be amplified by national and international media coverage. Adverse economic impacts would include the cost of emergency response, evacuation, decontamination and disposal; opportunity costs to affected individuals, property-owners, and businesses; and economic losses resulting from public perceptions of risk and stigma effects.

C. Reexamine Requirements for Advance Approval of Routes.

The Commission should reexamine its regulations requiring advance approval of routes. The current regulations require Commission approval of the routes to be used for road and rail shipments of SNF. (10 C.F.R. 73.37(b)(7)) Advance route approvals are part of a safeguards system designed to "[m]inimize the possibilities for radiological sabotage of spent fuel shipments, especially within heavily populated areas . . . ." (10 C.F.R. 73.37(a)(1)(i)) In 1980, the Commission issued a regulatory guidance document which identified five types of route characteristics that receive special consideration when the Commission staff reviews requests for route approval: (1) routes through highly populated areas; (2) routes which would place the shipment or the escort vehicle in a significantly tactically disadvantageous position (for example, tunnels which would prevent the escort vehicle from maintaining continuous surveillance of the shipment vehicle); (3) routes with marginal safety design features (for example, two-lane routes, absence of guard rails, etc.); (4) routes with limited rest and refueling locations; and (5) routes where responses by local law enforcement agencies, when requested, would not be swift or timely.[2]

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[2] U.S. Nuclear Regulatory Commission, Office of Nuclear Material Safety and Safeguards, *Physical Protection of Shipments of Irradiated Reactor Fuel: Interim Guidance*, NUREG-0561, Revision 1 Washington DC: U.S. Nuclear Regulatory Commission, June, 1980, at 20-5.

Petitioner believes that the Commission should thoroughly reexamine its advance route approval requirements, in light of the expected dramatic increase in SNF shipments once a Federal repository or interim storage facility begins operations. Neither the current physical protection regulations, nor the U.S. Department of Transportation's routing regulations, require shippers and carriers to minimize shipments through highly populated areas. Since 1979, the Commission has approved many highway routes through heavily populated areas, including I-15 through Las Vegas and I-80 through Reno-Sparks.[3] A transportation risk assessment recently published by the Commission assumes that tens of thousands of truck shipments to a repository at Yucca Mountain could travel through Las Vegas and other heavily populated areas of Clark County, Nevada.[4]

Moreover, neither the current physical protection regulations, nor any of the U.S. Department of Transportation's routing regulations, require shippers and carriers to follow the Commission's route selection criteria as set forth in NUREG-0561. The U.S. Department of Energy is currently evaluating highway and rail routes to Yucca Mountain which do not comply with the Commission's route selection criteria. The Petitioner is submitting an analysis of highway and rail routes currently under consideration in Attachment B, Planning Information Corporation, *The Transportation of Spent Nuclear Fuel and High-Level Waste: A Systematic Basis for Planning and Management at National, Regional, and Community Levels* at 43-100 (September 10, 1996).[5] Attachment A identifies Nevada highway and rail routes currently under consideration which include tunnels, steep grades, sharp curves and other features that would place shipments or escorts in tactically disadvantageous positions; routes with marginal safety design features; routes with limited rest and refueling locations; and routes with a low likelihood of swift local law enforcement agency response. Attachment A at 10-22.

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[3] U.S. Nuclear Regulatory Commission, Spent Fuel Project Office, Office of Nuclear Material Safety and Safeguards, *Public Information Circular for Shipments of Irradiated Reactor Fuel*, NUREG-0725, Rev. 13, October, 1998, Washington DC US Nuclear Regulatory Commission at 3-9.

[4] U.S. Nuclear Regulatory Commission, *Generic Environmental Impact Statement for License Renewal of Nuclear Plants, Main Report, § 6.3 - Transportation, Draft Report for Comment*, NUREG-1437, Vol. 1, Addendum 1, 2-5 (February, 1999).

[5] Report prepared for Nevada Nuclear Waste Project Office, Carson City, Nevada.

Petitioner requests that the Commission, as part of a comprehensive reassessment of the consequences of terrorist attacks, consider amending the advance route approval requirements. The Petitioner believes that the Commission should specifically require shippers and carriers to identify primary and alternative routes which minimize highway and rail shipments through heavily-populated areas. Petitioner also believes the Commission should adopt the route selection criteria in NUREG-0561 as part of the regulations, and specifically require shippers and carriers to minimize use of routes which fail to comply with the route selection criteria.

D. *Amend Escort Requirements for Shipments by Road*

The Commission should reexamine its regulations requiring armed escorts for SNF shipments by road. The current regulations establish one armed escort standard for shipments "within a heavily populated area" (10 C.F.R. 73.37(1)) and a lesser escort standard for shipments "not within any heavily populated area." (10 C.F.R. 73.37(2)) For purposes of regulating SNF shipments, the Commission designates heavily populated areas as urbanized areas having a population of 100,000 or more persons, based on population data and boundaries determined by the Bureau of the Census. "A shipment within three miles of the boundary of a designated urbanized area, or located anywhere within a designated urbanized area, is considered to be within a heavily populated area."[6]

The current regulations require that for road shipments within heavily populated areas, the transport vehicle must be:

> (i) occupied by at least two individuals, one of whom serves as escort, and escorted by an armed member of the local law enforcement agency in a mobile unit of such agency; or (ii) led by a separate vehicle occupied by at least one armed escort, and trailed by a third vehicle occupied by at least one armed escort. (10 C.F.R. 73.37(1))

Petitioner requests that the Commission amend its regulations to eliminate the differential armed escort requirements based on population. The current requirement for shipments within a heavily populated area should be uniformly applied to all road shipments. As a matter of equity, Petitioner believes that residents of small cities, towns, and rural areas along shipment routes are entitled to the same level of protection as residents of heavily populated areas. As a practical matter,

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[6] NUREG-0561, Rev. 1, p.8

there are many Nevada locations outside of designated heavily populated areas with significant population concentrations within one-half mile of a potential SNF shipment route. Many difficult-to-evacuate facilities, such as schools, hospitals, industrial plants, shopping centers, hotels, and resorts, are located immediately adjacent to potential truck shipment routes in small cities and towns. Several major water supplies and outdoor recreation facilities with high seasonal population densities are located in close proximity to potential truck shipment routes in rural Nevada.

Petitioner further requests that the Commission, as part of a comprehensive reassessment of the consequences of terrorist attacks, consider increasing the armed escort requirements for truck shipments. Petitioner believes that new, high-capacity, legal-weight truck SNF shipping cask designs may be particularly vulnerable to attacks involving high-energy explosive devices. At a minimum, the Commission should consider requiring at least one armed escort each in a lead vehicle and a chase vehicle, with one escort being a state or local law enforcement officer. The Commission's consequence assessment should evaluate the advantages and disadvantages of requiring the same level of protection provided for truck shipments of strategic special nuclear materials, seven armed escorts in two escort vehicles (10 C.F.R. 73.26(i)).

E. Amend Escort Requirements for Shipments by Rail

The Commission should reexamine its regulations requiring armed escorts for SNF shipments by rail. The current regulations establish one escort standard for shipments "within a heavily populated area" (10 C.F.R. 73.37(d)(1)) and a lesser escort standard for shipments "not within any heavily populated area." (10 C.F.R. 73.37(d)(2)). For purposes of regulating SNF shipments, the Commission designates heavily populated areas as urbanized areas having a population of 100,000 or more persons, based on population data and boundaries determined by the Bureau of the Census. "A shipment within three miles of the boundary of a designated urbanized area, or located anywhere within a designated urbanized area, is considered to be within a heavily populated area."[7]

The current regulations require that for rail shipments within heavily populated areas, the shipment car must be: "accompanied by two armed escorts (who may be members of a local law

[7] NUREG-0561, Rev. 1, p.8.

enforcement agency), at least one of whom is stationed at a location on the train that will permit observation of the shipment car while in motion." (10 C.F.R. 73.37(d)(1))

Petitioner requests that the Commission amend its regulations to eliminate the differential armed escort requirements for rail shipments based on population. The current requirement for shipments within a heavily populated area should be uniformly applied to all rail shipments. In Nevada and other western states, many small cities and towns grew up around rail lines and rail service facilities. In these communities, there are significant population concentrations within one-half mile of a potential SNF rail shipment route. In Nevada and other western states, mainline railroads are frequently located in river valleys near major water supplies. Additionally, mainline railroads of national economic significance may, in-and-of themselves, be as attractive targets for terrorists as heavily populated areas. The Union Pacific Salt Lake City-Los Angeles mainline through southern Nevada, potentially the primary shipment route to Yucca Mountain, is a rail route of national economic significance.

Petitioner further requests that the Commission, as part of a comprehensive reassessment of the consequences of terrorist attacks, consider substantially increasing the armed escort require-ments for rail shipments. Petitioner believes that new, high-capacity (125 ton) rail shipping cask designs may be particularly vulnerable to attacks involving antitank missiles, and that armed escorts aboard the train could be incapacitated at the beginning of an attack, or as a result of train derailment. At a minimum, the Commission should consider requiring at least two armed escorts in an escort vehicle in addition to the two armed escorts aboard the train.

Based on recent experience during the foreign research reactor SNF shipments throug Nevada, Petitioner believes the Commission should also consider requiring continuous, real-tim aircraft surveillance along certain rail route segments through rough terrain and through heavil populated areas. The Commission's consequence assessment should evaluate the advantages an disadvantages of requiring a level of protection comparable to that provided for rail shipments of strategic special nuclear materials, seven armed escorts (10 C.F.R. 73.26(k)), stationed in a varie of configurations aboard the train and in one or more escort vehicles.

F. Adopt Additional Planning and Scheduling Requirements

The Commission should adopt additional planning and scheduling requirements for the physical protection of SNF shipments based on the precautions already applied to shipments of special nuclear materials. The current regulations for shipments of special nuclear materials require:

> Shipments shall be scheduled to avoid regular patterns and preplanned to avoid areas of natural disaster or civil disorders, such as strikes or riots. Such shipments shall be planned in order to avoid storage times in excess of 24 hours and to assure that deliveries occur at a time when the receiver at the final delivery point is present to accept the shipment. (10 C.F.R. 73.26(b)(1))

Petitioner requests that the Commission, as part of a comprehensive reassessment of the consequences of terrorist attacks, consider amending the general requirements for physical protection of irradiated reactor fuel in transit (10 C.F.R. 73.37(b)) by adopting the same planning and scheduling requirements for special nuclear material in transit.

G. Amend Regulations To Require That All Rail Shipments Be Made In Dedicated Trains

The Commission should amend its regulations for shipments by rail (10 C.F.R. 73.37(d)) to require that all rail shipments of SNF be made in dedicated trains. Considering the potential large number of cross-country rail shipments to a repository and/or storage facility, more than 12,000 rail cask shipments of SNF and more than 1,000 rail cask shipments of HLW, Petitioner believes that the performance objectives set forth in 10 C.F.R. 73.37(a)(1) can only be met by requiring all rail shipments to be made in dedicated trains. Petitioner further requests that the Commission, as part of a comprehensive reassessment of the consequences of terrorist attacks, consider the physical protection implications of shipping SNF in dedicated trains compared to general rail freight service.

Petitioner, along with other stakeholders including the Association of American Railroads, has long advocated mandatory use of dedicated trains for all rail shipments of SNF in order to promote safety and security. The U.S. Nuclear Waste Technical Review Board recently stated: "One possible approach to maximizing safety and to preventing undue burdens on the nationwide railroad network could be the use of dedicated trains for transporting spent nuclear fuel."[8] While continuing to believe that use of dedicated trains should be mandatory, Petitioner acknowledges arguments that dedicated

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[8] *Report to the U.S. Congress and the Secretary of Energy* at 23 (January to December 1998).

trains may pose certain disadvantages from a physical protection standpoint. For example, dedicated trains may facilitate target tracking and attack scheduling by potential adversaries, and multiple casks in a short train may facilitate target selection and weapon delivery. The Commission's consequence assessment should evaluate the advantages and disadvantages of shipping SNF in dedicated trains, assuming both current and enhanced requirements for rail shipment armed escorts.

H. *Conduct A Comprehensive Assessment Of The Consequences Of Terrorist Attacks That Have The Capability Of Radiological Sabotage*

Petitioner further respectfully requests and petitions the Commission to conduct a comprehensive assessment of the consequences of terrorist attacks that have the capability of radiological sabotage, including attacks against transportation infrastructure used during nuclear waste shipments, attacks involving capture of a nuclear waste shipment and use of high energy explosives against a cask or casks, and direct attacks upon a nuclear waste shipping cask or casks using antitank missiles or other military weapons. Petitioner is submitting a recommended general approach for conducting such an assessment in Attachment A at 31-48. Petitioner is submitting specific guidelines for assessing the consequences of terrorist attacks employing antitank weapons in Attachment A at 49-71.

II. GROUNDS AND INTEREST

Petitioner State of Nevada (Nevada) has been, and will likely continue to be, a corridor state for spent nuclear fuel (SNF) shipments. Nevada has been a destination and origin state for SNF shipments to and from federal research facilities. As the potential host state for a federal geologic repository and/or interim storage facility, Nevada would be the ultimate destination for the entire nation's SNF and high-level radioactive waste (HLW). Nevada has an interest in protecting its citizens from risks associated with the transportation of SNF and HLW. Nevada also has an interest, as the entity responsible for immediate emergency response, in ensuring that transporters of spent nuclear fuel have adequately prepared for potential emergencies. Nevada is particularly concerned about the physical protection of shipments of SNF under the Commission's regulations at 10 C.F.R. Part 73.

Between 1964 and 1998, Nevada was traversed by approximately 321 truck shipments and 16 rail shipments of civilian SNF to and from nuclear reactor sites, research facilities, and interim storage facilities.[9] Nevada will likely continue to be a corridor state for SNF shipments to and from the Idaho National Engineering Laboratory. Nevada would also likely be traversed by SNF shipments to and from the Private Fuel Services storage facility proposed for the Skull Valley Goshute Reservation in Utah.

Petitioner's primary interest is the potential for many thousands of SNF and HLW shipments to Yucca Mountain and the Nevada Test Site. The Nuclear Waste Policy Amendments Act (NWPAA) designated Yucca Mountain as the only site to be characterized for a national geologic repository for SNF and HLW. Legislation pending in Congress would designate the Nevada Test Site as sole location for a centralized interim storage facility. According to a study prepared for the Nevada Agency for Nuclear Projects, the base case projection for repository transportation requirements is 20,200 shipments (13,900 rail/6,300 truck) over about 30 years. The same study projected 56,600 to 104,500 shipments over 40 years, for a repository combined with an interim storage facility. *See* Attachment B at 61-4. A recent study prepared for the Commission estimated 50,000 to 75,000 shipments to Yucca Mountain if all civilian SNF were transported by truck.[10]

While repository shipments are not scheduled to begin until 2010 or later, the U.S. Department of Energy (DOE) has already begun planning for transportation to a repository at Yucca Mountain. DOE plans to release a draft EIS addressing transportation risks and impacts in July, 1999. Cross-country SNF shipments to Nevada could begin as early as 2004 if Congress enacts interim storage facility legislation.

Under the NWPAA, DOE is responsible for the transportation of SNF and HLW from more than 80 generator and storage sites to the repository. Once repository and/or storage facility operations begin, DOE shipments of SNF and HLW will impact more than 40 states, dozens of Indian nations, and hundreds of cities and local governments. For the first time in its history, DOE

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[9] U.S. Department of Energy, *Nevada Commercial Spent Nuclear Fuel Transportation Experience*, YMP/91-17, 5-7 (September 1991), U.S. Nuclear Regulatory Commission, Public Information Circular for Shipments of Irradiated Reactor Fuel, NUREG-0725, Rev. 13, 6-7, 20-21, (October 1998)). An unknown number of naval reactor SNF shipments traveled through Nevada during the same period.

[10] U.S. Nuclear Regulatory Commission, *Generic Environmental Impact Statement for License Renewal of Nuclear Plants, Main Report, § 6.3 - Transportation, Draft Report for Comment*, NUREG-1437, Vol. 1, Addendum 1, 2-5 (February, 1999).

will ship SNF and HLW as a fully regulated licensee of the Commission. The NWPAA specifically requires that DOE transport SNF and HLW in accordance with the Commission's regulations promulgated under 10 C.F.R. parts 71 and 73. Petitioner Nevada is particularly concerned about the physical protection of DOE shipments of SNF under the Commission's regulations at 10 C.F.R. part 73.

Spent nuclear fuel shipments to a geologic repository and/or centralized interim storage facility will be dramatically different from past shipments in the United States. *See* Attachment A at 18-22. Petitioner Nevada believes the following differences, discussed in detail in Attachment A, will create greater opportunities for terrorist attacks and/or sabotage against SNF shipments, and may also increase the consequences of any incidents which occur:

(a) long-duration, highly visible, nationwide shipping campaign;

(b) regular and predictable shipments, to a single destination;

(c) large increase in amount of spent fuel shipped, and increased numbers of truck and rail shipments annually, averaging several cask shipments per day, every day, for 30 years;

(d) substantial increase in number of active routes and average shipment distances, with potential implications for selection of targets and attack locations;

(e) significant concentration of shipments along certain highway and rail routes west of the Mississippi River, with implications for shipments through heavily populated areas (HPAs) and through locations which place shipments in significantly disadvantageous tactical positions; and

(f) potential use of routes within Nevada with marginal safety design features, limited rest and refueling locations, and low likelihood of swift local law enforcement agency response.

Petitioner believes that a national repository or interim storage facility may have a greater symbolic value to terrorists as a target for attack than current at reactor storage facilities, and that the enhanced symbolic value of the facility as a target may extend to SNF shipments to such a facility. In its review of national storage and disposal policy options, the U.S. Nuclear Waste Technical Review Board (NWTRB) observed that compared to reactor sites "a single facility with a large stockpile of spent fuel might be a more tempting and visible target."[11] Petitioner concurs with the NWTRB conclusion that more analyses are needed to determine if "either an at-reactor or centralized storage facility would be more exposed to theft or sabotage." and that such analyses should also consider SNF shipments to a centralized facility. Petitioner requests that the Commission consider this issue in rulemaking.

Petitioner further believes that a storage or disposal facility operated by DOE, the U.S. government agency responsible for producing nuclear weapons, may have greater symbolic value to terrorists as a target for attack than commercial storage facilities, and that the enhanced symbolic value may extend to DOE's shipments of SNF and HLW to such a facility. In the mid-1980s, DOE's Inspector General commissioned two studies of potential terrorist threats against DOE nuclear facilities and programs. Both reports, prepared for DOE by the Rand Corporation and published in 1986, identified potential domestic and foreign threats to DOE nuclear facilities, and recommended continued safeguards vigilance and further studies.

The first study concluded:

> With their greater resources and lesser political concerns, state-sponsored terrorist groups could constitute a significant danger to nuclear weapons sites. This not to say that the threat from domestic terrorist groups is negligible. On the basis of past modus operandi, targeting, motivation, and mindset, Islamic fanatics, right-wing terrorists, left-wing terrorists, and Puerto Rican separatists could conceivably attack a nuclear installation.[12]

The subsequent reassessment concluded:

> Increased visibility of American nuclear programs could make them inviting targets for disruptive and destructive missions. The increased resources of state-sponsored terrorists (and the concomitant use by states of terrorists as instruments of national policy) should alert policy makers against any relaxation of the safeguards regimen. Renewed analysis of nuclear safeguards should be actively considered, even though current trends do not indicate any immediate or pressing danger.[13]

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11 *Disposal and Storage of Spent Nuclear Fuel - Finding the Right Balance: A Report to Congress and the Secretary of Energy* at 20 (March 1996).

12 Bruce Hoffman, *Terrorism in the United States and the Potential Threat to Nuclear Facilities*, prepared for the U.S. Department of Energy, Rand Publication Series, R-3351-DOE, at 53 (January 1986).

13 Bruce Hoffman, et al., *A Reassessment of Potential Adversaries to U.S. Nuclear Programs*, prepared for the U.S. Department of Energy, Rand Publication Series, R-3363-DOE, at 25-6 (March, 1986).

Petitioner believes that DOE SNF facilities and shipments may be peculiarly attractive targets to a wide range of enemies of the United States, and requests that the Commission consider this issue in rulemaking.

III. STATEMENT IN SUPPORT OF PETITION

A. *Request for Amendments to Current Regulations*

Petitioner believes that the Commission should amend the current safeguards regulations in order to better deter, prevent, and mitigate the consequences of any attempted radiological sabotage against shipments of spent nuclear fuel. The Commission last publicly addressed the consequences of terrorist attacks on SNF shipments and the adequacy of its safeguards regulations in 1984. The Petitioner believes that a general strengthening of the regulations intended to safeguard SNF shipments is necessary because of new developments in two critical areas since 1984: (1) changes in the nature of the terrorist threat; and (2) increased vulnerability of shipping casks to terrorist attacks involving high-energy explosive devices.

1. **Changes in the nature of the terrorist threat**. The nature of the terrorist threat has changed significantly since the Commission last evaluated the adequacy of its SNF transportation safeguards regulations. In the decade and a half since 1984, three major changes have occurred in the nature of the terrorist threat that argue for a strengthening of the safeguards regulations: (1) the increasing lethality of terrorist attacks in the United States; (2) an increase in serious terrorist attacks and threats against transportation systems; and (3) renewed concerns about nuclear terrorism generally, and specifically, terrorist actions involving potential radioactive contamination.[14]

The lethality of terrorist intentions was generally down played at the time the Commission last publicly considered the consequences of a terrorist attack on a spent fuel shipment. A 1980 contractor study prepared for the Commission reported:

> Pronuclear activists and the nuclear industry believe radioactive materials, in general, are highly overrated as targets for acts of sabotage

[14] The following discussion is primarily based on, and documented in, Attachment A at 31 - 48; and James David Ballard, A *Preliminary Study of Sabotage and Terrorism as Transportation Risk Factors Associated with the Proposed Yucca Mountain High-Level Nuclear Waste Facility*, NWPO-TN-018-96, Published by State of Nevada Agency for Nuclear Projects, 9-24, 34-49 (September 1997).

> to produce widespread death and destruction or for acts of theft for purposes of weapons fabrication. A crude nuclear device requires technical expertise to construct, which is usually not available in today's terrorist organizations. Such terrorist groups would find it easier to try to disperse radioactive materials through other means, such as by dynamite. Still, it has not been the pattern of terrorist groups in the past to kill large numbers of people or to cause large numbers of lingering deaths. Terrorist groups have typically used violent means to make a political statement. "Terrorists want a lot of people watching, not a lot of people dead."[15]

During the past few years, however, the willingness of terrorists to kill large numbers of Americans has been demonstrated in the World Trade Center and Oklahoma City bombings. The Federal Bureau of Investigation (FBI) reported in 1995: "*In the past year, the country witnessed the re-emergence of spectacular terrorism with the Oklahoma City bombing. Large-scale attacks designed to inflict mass casualties appear to be a new terrorist method in the United States.*" The Oklahoma City bombing reflected a "*general trend in which fewer attacks are occurring in the United States, but individual attacks are becoming more deadly.*" The FBI voiced concern about terrorist interest in advanced technologies and improving terrorist capabilities regarding electronic communications, computer databases, and analysis of past events which "could prompt future terrorists to plan their attacks with greater care." The FBI also noted "a chilling trend" in continued terrorist interest in unconventional weapons such as biological agents, concluding that "terrorists and other criminals may consider using unconventional weapons in an attack here sometime in the future."[16] The willingness of terrorists to kill or injure large numbers of Americans, demonstrated in the World Trade Center and Oklahoma City bombings, compels a focus on incidents which are clearly intended to cause, or could cause, radiological sabotage.

One of the most comprehensive recent terrorism studies, *America's Achilles Heel* by Falkenrath, Newman, and Thayer, attributes the increasing lethality of attacks to increased terrorist activity by "violent non-state actors:"

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[15] C. Cluett, et al., *Identification and Assessment of the Social Impacts of Transportation of Radioactive Materials in Urban Environments*, Prepared by Battelle Human Affairs Research Centers, NUREG/CR-0744, Washington D.C.: U.S. Nuclear Regulatory Commission at 100 (July 1980).

[16] Terrorist Research and Analytical Center, National Security Division, *Terrorism in the United States : 1995*, Washington DC: U.S. Department of Justice, Federal Bureau of Investigation at i,14-15 (no date).

> Terrorist groups and most other non-state actors have historically had little interest in killing large numbers of people with their attacks, and for many non-state actors, the reasons for this aversion will remain compelling. Nonetheless, non-state violence appears to be growing more lethal: mass-casualty terrorist attacks are becoming more frequent, and the percentage of attacks that result in fatalities is increasing. The best explanation for this trend is that there are increasing numbers of violent non-state actors for whom the logic of limited lethality applies only weakly, such as fanatical religious groups and cults, anti-American Islamic extremists in the Middle East, right-wing chauvinists, and loosely affiliated terrorists who lack the traditional concern with group preservation.[17]

Terrorism threats against transportation systems have increased since the Commission's 1984 consequence assessment. The FBI reported in 1996:

> Recently, terrorist attacks against aircraft and other transportation facilities, both here in the United States and abroad, have taken a disturbing upswing. Examples include the conspiracy by Ramzi Ahmed Yousef and others to bomb U.S. airliners in Asia in 1994; the derailment of an Amtrak passenger train near Hyder, Arizona, in October 1995, which killed 1 and injured 78; and the bombing of the World Trade Center in February 1993, which substantially damaged the Port Authority Transportation and Housing Railway Line. The latter is a major commuter line running from New Jersey to New York City. At one point, it passes through the parking garage of the World Trade Center Complex, where the 1,200-pound urea nitrate bomb detonated. Less than four months later, a group of followers of Shaykh Omar Abdel Rahman planned to use explosives to unleash a campaign of terror in New York City. Their targets included the Lincoln and Holland Tunnels, major arteries into and out of New York City. Obviously, the worldwide terrorist threat to aviation and transportation systems still exists, both within the United States and outside.[18]

The George Washington Bridge on Interstate 95 was one of the facilities targeted for bombing by the followers of Sheik Omar Abdel Rahman. The George Washington Bridge is a major gateway from Manhattan, Long Island, and New England into New Jersey for trucks traveling I-95 to the South and I-80 to the West, and has previously been used for truck shipments of irradiated reactor fuel and plutonium from Brookhaven National Laboratory to the Savannah River Plant in South Carolina. The George Washington Bridge could potentially be used for truck shipments of spent fuel from Connecticut reactors to a storage or disposal site in Nevada. Attachment A at 40-41.

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[17] R.A. Falkenrath, R.D. Newman, and B.A. Thayer, *America's Achilles Heel: Nuclear, Biological, and Chemical Terrorism and Covert Attack*, Cambridge, MA: The MIT Press at 214 (1998).

[18] Counter-Terrorism Threat Assessment and Warning Unit, National Security, Division, *Terrorism in the United States: 1996*, Washington D.C.: U.S. Department of Justice, Federal Bureau of Investigation at 24 (no date).

Lessons learned from the 1995 Arizona derailment and previous incidents of rail sabotage and from the Abdel Rahman transportation terrorism prevention. include four findings about the intentions and capabilities of potential adversaries: (1) their willingness to attack trains, bridges, and tunnels without warning shows a willingness if not an intention to kill, maim, and terrify tens to hundreds of people at a time; (2) their technical expertise in planning their attacks, at least in the case of the rail sabotage events, may be sufficient to defeat existing warning systems; (3) their ability to cause accident conditions such as 50 mph collisions and 30 foot drops, demonstrates their ability to at least challenge the containment performance standards of NRC-certified shipping containers; and (4) attacks on infrastructure may be carried out with use of homemade explosives and do not require the procurement of exotic weapons to be successful. Attachment A at 41-42.

Concerns about nuclear terrorism generally have increased significantly since the early 1990s. Recent threat assessments have addressed potential terrorist use of nuclear weapons, potential terrorist actions to disperse radioactive contamination using so-called "radiological weapons," and reactor sabotage.[19] Indeed, the Commission responded to similar concerns by adopting new safeguards regulations in 1994 to protect commercial nuclear reactors from attacks using truck bombs.

The U.S. Interagency Counterproliferation Program Review Committee (CPRC) 1997 Report to Congress summarized potential threats resulting from terrorist acquisition of nuclear weapons and dispersal of radioactive materials utilizing conventional weapons. Based on extensive literature reviews, the CPRC concluded:

> [N]on-fissile radioactive materials dispersed by a conventional explosive or even released accidentally could cause damage to property and the environment, and cause social, political, and economic disruption. Examples of non-fissionable, radioactive materials seen in press reports are cesium-137, strontium-90, and cobalt-60. These cannot be used in nuclear weapons but could be used to contaminate water

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[19] See for example: Robert W. Marrs, "*Nuclear Terrorism: Rethinking the Unthinkable*", MA Thesis, Naval Postgraduate School, Monterey, CA (December 1994); Peter J. DiPaolo, "*Motivations for Nuclear Terrorism in the United States*," MA Thesis, Naval Postgraduate School, Monterey, CA (June 1995); Stanley S. Jacobs, "*The Nuclear Threat as a Terrorist Option*," Paper Presented at the Annual Meeting of the American Society of Criminology, San Diego, CA (November 19-22, 1997); and Denise A. DeLawter, "*Nuclear Weapons, Proliferation, and Terrorism: U.S. Response in the Twenty-First Century*," MA Thesis, U.S. Army Command and General Staff College, Fort Leavenworth, KS (June 1998).

> supplies, business centers, government facilities, or transportation networks. Although it is unlikely they would cause significant numbers of casualties, they could cause physical disruption, interruption of economic activity, and psychological trauma to the work force and general populace, and require some measure of post-incident cleanup.[20]

Falkenrath, Newman, and Thayer conclude similarly:

> The simplest radiological weapon would consist of a conventional explosive surrounded by a quantity of any radioactive material. Crude radiological weapons are far more accessible than nuclear weapons, and are therefore more likely to be used by non-state actors. However, although a radiological weapon could contaminate an area and be costly to clean up, building and using such a weapon is not an easy way to produce mass casualties. Large quantities of highly radioactive material would generally be needed to produce strong effects over even a moderate area. Obtaining and working with large amounts of such materials would be challenging because of the high radiation levels involved. Due to widespread public fear of radiation, however, a radiological attack might trigger panic and social and economic disruption out of proportion with its real destructiveness.[21]

According to the CPRC, there have been threats but no actual radiological contamination incidents by terrorist groups to date. In 1995, Chechen insurgents threatened to turn Moscow into an "eternal desert" by dispersing cesium-137.

> The Chechens directed a Russian news agency to a small amount of cesium-137 in a shielded container in a Moscow Park which the Chechens claimed to have placed there. Government spokesmen told the press that the material was not a threat, and would have to have been dispersed by explosives to be dangerous. According to DoD assessments, there was only a very small quantity of cesium-137 in the container. If it had been dispersed with a bomb, an area of the park could have been contaminated with low levels of radiation. This could have caused disruption to the populace, but would have posed a minimal health hazard for anyone outside the immediate blast area.[22]

The CPRC also noted that the Japanese Aum Shinrikyo cult "which twice attacked Japanese civilians with deadly sarin nerve gas, also tried to mine its own uranium in Australia and to buy Russian nuclear warheads."[23]

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[20] Counterproliferation Program Review Committee (CPRC), *Report on Activities and Programs for Countering Proliferation and NBC Terrorism*, Washington, DC: U.S. Congress, 3-4 (May 1997).

[21] *America's Achilles Heel*, at 15.

[22] Counterproliferation Program Review Committee(CPRC), *Report on Activities and Programs for Countering Proliferation and NBC Terrorism*, Washington, DC: U.S. Congress, 3-4 (May 1997).

[23] *Ibid.*

On March 2, 1999, Secretary of Energy Bill Richardson began his speech to the National Press Club by disclosing a previously unreported threat:

> The FBI receives word of a phone threat that radioactive material is aboard an AMTRAK train in Montana and that its passengers are in danger. Within hours, specialists including the Department of Energy's Nuclear Emergency Search Team arrive. Both the eastbound and westbound trains are diverted to a lonely stretch of track and searched for a potential killer. This is not a plot twist in a Tom Clancy thriller nor a figment of a Hollywood screenwriter's imagination. This incident occurred February 20th, aboard the Empire Builder in central Montana. No radioactive material was found. No one was injured. This time.[24]

To Petitioner's knowledge, only two threats against spent fuel shipments have been reported in the United States since 1984. In November, 1984, Northern States Power (NSP) began shipping spent fuel from the Monticello reactor north of the Twin Cities to the General Electric storage facility at Morris, Illinois. On February 4, 1985, NSP corporate headquarters received a telephone threat warning that a group of anti-nuclear protesters would use a small airplane to stop a train carrying spent fuel from Monticello to Morris.[25] On October 27, 1986, a person or persons unknown removed a 39-foot long section of rail along the Burlington Northern route used for these shipments in Golden Valley, Minnesota.[26] Near the tracks authorities found a sign reading "Stop Rad-Waste Shipments." This incident did not result in damage to the train transporting spent fuel. However, a Burlington Northern train hauling lumber, scheduled immediately prior to a train transporting spent fuel from Monticello, derailed at the site of the sabotage. The initial investigation focused on anti-nuclear activists and disgruntled railroad employees. Attachment A at 37-9

The October, 1986 apparent attempted sabotage of a spent fuel shipment has not been studied in detail. The incident is not reported in the relevant volume of the Commission's *Safeguards Summary Event List* (SSEL). The omission of this incident is curious because Governor Tony Earl of Wisconsin, a state along the route, formally notified the Chairman of the Commission of his concerns

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[24] "*Securing America from Emerging Threats in the 21st Century*," Department of Energy Secretarial Speeches, <http://home.doe.gov/news/speeches99/marss/ussec21.htm>.

[25] Preliminary Notification of Event or Unusual Occurrence, PNO-III-85-15, Date February 2, 1985, Subject: THREAT AGAINST SPENT FUEL SHIPMENT, PDR, 8502080205 850201.

[26] Preliminary Notification of Event or Unusual Occurrence, PNO-III-86-123, Date October 27, 1986, Subject: APPARENT SABOTAGE OF RAIL LINE, PDR, 8611040366-861027.

about the reported sabotage incident and requested specific regulatory and investigative actions by the Commission.[27] The omission of the incident from the SSEL is incongruous considering that the SSEL does report the February 4, 1985 telephone threat.[28] Petitioner Nevada believes the 1986 Minnesota incident is evidence of a credible risk of terrorism or sabotage against nuclear waste shipments, specifically damage to transportation infrastructure with the intent of causing an accident, although there is no clear evidence that the perpetrators intended to damage the shipping casks or cause a release of radioactive materials. Attachment A at 37-9.

Falkenrath, Newman, and Thayer point out: "The absence of attacks can be mistaken for the absence of vulnerability, since both have identical manifestations."[29] Petitioner Nevada believes that the threat of a terrorist attack on a spent fuel shipment capable of causing radiological sabotage should be considered credible, even though no such attacks have occurred. Petitioner requests that the Commission judge the potential threat to spent fuel shipments by the same standard it applied in adopting additional safeguards regulations to protect reactors from truck bomb attacks:

> NRC has concluded there is no indication of an actual vehicle threat against the domestic commercial nuclear industry. However, based on recent events, NRC believes that a vehicle intrusion or bomb threat to a nuclear power plant could develop without warning in the future. To maintain a prudent margin between what is the current threat estimate (low) and the design basis threat (higher), NRC is amending 10 C.F.R. 73 to modify the design basis threat for radiological sabotage to include protection against malevolent use of vehicles at nuclear power plants.[30]

2. **Increased vulnerability of shipping casks to terrorist attacks involving high-energy explosive devices**. Developments in two related areas have increased the vulnerability of spent fuel shipping casks to terrorist attacks involving high-energy explosive devices since the Commission last evaluated the adequacy of its SNF transportation safeguards regulations. First, the capabilities and availability of explosive devices, especially antitank weapons, have increased significantly. Second,

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[27] Preliminary Notification of Events or Unusual Occurrence, TNO-III-86-123A, Date October 31, 1986, Subject: APPARENT SABOTAGE OF RAIL LINE-UPDATE, PDR, 8611070025 861031

[28] *Safeguards Summary Event List: Pre-NRC through December 31, 1989*, NUREG-0525, Vol. 1, Washington DC: U.S. Nuclear Regulatory Commission, at 381 (July 1992).

[29] *America's Achilles' Heel*, at 145.

[30] D.K. Rathbun to J. Lieberman, July 28, 1994, 73 59FR14085 PDR 9408110274 40728

new spent fuel shipping cask designs, developed to increase payloads without exceeding specified weight limits, appear to be more vulnerable to attacks involving past, current, and future weapons systems and commercial explosives. These developments argue for a strengthening of the safeguards regulations.

Portable antitank weapons have become more powerful, more reliable, and more available worldwide since the early 1980s. This development is documented in Attachment A at 49-63.[31] Publicly available performance data on some of the better known antitank missiles is summarized in Attachment A, Table 5. Under the current design basis threat (10 C.F.R. 73.1(a)(1)(i)), Petitioner believes that the definition of hand-carried equipment, in the hands of several well-trained and dedicated attackers, using a four-wheel drive vehicle to carry their equipment, includes (but is not limited to) all of the weapons identified in Attachment A, Table 5.

Petitioner believes that most, if not all, of the antitank missiles identified have warheads capable of completely perforating a truck cask and its spent fuel cargo, and most are capable of deeply penetrating or completely perforating a rail cask and damaging the spent fuel inside. These weapons are designed to hit moving targets at a distance of 30 meters or more, eliminating the need to capture the cask, and facilitating selection of optimal attack times and locations. Portability of these weapons allows further flexibility in attack planning, including use of multiple warheads, and in escape planning. Many different types of antitank missiles are currently being produced, in many different countries, and in some instances, tens to hundreds of thousands of units of particular designs have been produced. Most older weapons have been used in battle, and newer versions have been extensively field tested. The limitations and deficiencies of specific weapons (such as backblast effects, operator error in guidance control, guidance system failure, fuse and warhead failure) are known, and can be factored into a consequence assessment. Given the general trend of improved armor penetration capability over the past four decades, it should be assumed that even more effective weapons will become available over the next four decades when repository shipments occur. Potential

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[31] See also, Chris Bishop, Editor, *The Vital Guide to Combat Guns and Infantry Weapons*, London: Airlife Publishing Limited, *at 103-115 (1996)*; Ian Hogg, *Tank Killing: Anti-Tank Warfare by Men and Machines*, New York: Sarpedon Publishers, at 54-64, 101-103, 170-202 (1996); and John Norris, *Anti-Tank Weapons*, London: Brassey's Inc., at 7-8, 92-95, 114-115, 130-132, 139-140 (1996).

adversaries could obtain such weapons through a variety of channels, including terrorist state-sponsorship, purchase, theft, or blackmail. Attachment A at 50-7.

Under the current design basis threat for radiological sabotage, man-portable versions of the TOW or Milan missiles, or their equivalent, should be used as the reference weapon for terrorism consequence assessment. The reference weapon should be assumed hand-carried to and from the four-wheel drive vehicle, transported to or near the attack site by the reference vehicle, operated by one to three persons, capable of firing up to three missiles, with a minimum range of 75 meters and a maximum range of 2,000. The reference weapon should be assumed capable of penetrating 25 to 40 inches of armor plate steel, with a hole diameter of 3 to 6 inches. A hit-probability of 90 percent or greater should be assumed. Attachment A at 59-63.

Petitioner believes that SNF shipping casks are vulnerable to attacks utilizing military and commercial explosives, particularly conical shaped charges. DOE sponsored tests in the early 1980s demonstrated that an attack on a truck cask using a large military shaped charge could result in a release of one percent of the SNF cargo. Commenting on those tests in response to the NRC's 1984 proposed reduction in transportation safeguards regulations, the Sierra Club Radioactive Waste Campaign took the position that terrorists might attack a cask more effectively with commercial explosives. "Sabotage of an irradiated fuel shipment could be relatively fast and simple, with explosive devices that are commercially available. Because of its long association with the military, Sandia Laboratories tested the military M3A1 shaped charge device, weighing 45 pounds." According to the Sierra Club reviewers:

> [E]ffective devices weighing much less, on the order of 1 1/2 pounds are available. A conical-shaped charge, <u>with an incendiary device</u>, . . . would be much more effective. Such a device could pierce 14 inches of metal, thus entering and exiting a shipping cask. The interior of the cask could be heated to 1,649 degrees C. This would ignite the zirconium cladding, further raising the temperature until the oxygen in the cask were exhausted. These temperatures would vaporize certain of the radionuclides, such as cesium. These devices [conical shaped charges] are commercially available and in use in well-drilling, spaceship and other applications. . . . We therefore disagree with the

NRC assumption that tens to hundreds of pounds of explosives are needed to disperse radioactivity from a shipping cask.[32]

Petitioner believes that the threat described by the Sierra Club reviewers in 1984 has grown more urgent in the decade of the 1990s. Well-trained terrorists planning to capture, control, and directly attack spent fuel shipping casks are likely to use shaped charges as their weapon of choice. The technology of shaped charges and detonation systems, especially for applications in the construction and petroleum industries, and for specialized purposes such as military demining, have continued to evolve since the early 1980s. Numerous "off the shelf" military and commercial shaped charges weighing around one kilogram are capable of penetrating 10 to 20 inches of steel.[33] Shaped charges developed for use in oil and gas well perforating are particularly powerful, efficient, and stable.[34] Secular oil-producing regimes such as Iraq and theocratic oil states such as Iran would have ready access to commercial shaped charges, as would governments, groups and individuals in natural gas and petroleum production regions around the world.

Petitioner believes that terrorists planning to attack transportation infrastructure are likely to use commercial or homemade explosives, rather than military devices. Indeed, most illegal bombings in United States are committed by perpetrators using non-military explosives. The vast majority of commercial explosives sales are used in the mining industries, and the bulk of these sales involve unpackaged ammonium nitrate and related explosives.[35] Ammonium nitrate explosives could be used in a variety of ways to attack the transportation infrastructure used for spent fuel shipments.

New spent fuel shipping cask designs. New spent fuel shipping cask designs, developed to increase payloads without exceeding specified weight limits, appear vulnerable to attacks involving current and future military weapons systems and commercial explosives. The casks used for

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[32] "Comments by the Sierra Club Radioactive Waste Campaign on Proposed Rule 10 CFR Part 73 Modification of Protection Requirements for Spent Fuel Shipments," prepared by Dr. Marvin Resnikoff, cited in Attachment A at 43-4.

[33] Paul W. Cooper and Stanley R. Kurowski, *Introduction to the Technology of Explosives*, New York: Wiley-VCH Inc., 132-157 (1996).

[34] Andrew Pettitt, "Perforating - An Oilfield Application of Explosives, " in John E. Dolan and Stanley S. Langer, *Explosives in the Service of Man: The Nobel Heritage*, Cambridge: Royal Society of Chemistry, 141-152 (1997).

[35] National Research Council, *Containing the Threat from Illegal Bombings*, Washington, D.C.: National Academy Press, 24-38 (1998).

shipments to a repository and/or interim storage facility shipments will have different design configurations and use different structural and shielding materials, compared to casks currently in use, and compared to the older casks which were assumed in the DOE and NRC sabotage consequence assessments in the early 1980s. Some of these differences may make them more vulnerable to attack with armor-piercing weapons or high-energy explosives.[36]

The majority of truck shipments to a repository and/or storage facility will likely use the new General Atomics GA-4 and GA-9 legal-weight truck casks, or new high-capacity casks of similar design. The side-to-side width of the GA-4 is 37 inches, with a shell containing 2 inches of stainless steel, 2.6 inches of depleted uranium, and 4.5 inches of borated polypropylene. The GA-9 is 35 inches wide, with a shell containing slightly more stainless steel and slightly less depleted uranium. The Petitioner believes that either of these casks would be completely perforated by an attack utilizing the reference antitank weapon and by most of the military weapons and commercial explosives previously discussed. Moreover, the GA 4/9 designs differ from the casks assumed in previous DOE and NRC radiological sabotage consequence assessments in several respects: rounded square versus circular body, polypropylene neutron shielded versus steel shelled water jacket, and depleted uranium gamma shield versus lead gamma shield. The first two of these differences could result in even greater vulnerability to attack with the reference weapon. The elimination of the water jacket could result in a larger release of respirable particulates.

The majority of rail shipments to a repository and/or interim storage facility will likely use new high-capacity casks similar to the Nuclear Assurance Corporation NAC-TSC, the Holtec HI-STAR 100, or the DOE-proposed design for the large MPC Rail Transporter. The diameter of the NAC-TSC is about 96 inches, with a shell containing 4.1 inches of stainless steel, 3.7 inches of lead, and 5.5 inches of borated polypropylene. The diameter of the HI-STAR 100 is about 96 inches, with a shell containing about 7 inches of stainless steel, 2.5 inches of carbon steel, and 4.6 inches of Holite neutron absorber. The diameter of the large MPC transportation cask is 85 inches, with a shell containing 5.25 inches of stainless steel, 1.5 inches of depleted uranium, 0.5 inches of lead, and

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[36] The following discussion is based on Attachment A, at 63-9, and Marvin Resnikoff to Bob Halstead, Unpublished Memorandum Report on HI-STAR 100 Shipping Cask Vulnerability Assessment at 1-4 (October 21, 1998).

6 inches of borated polypropylene. Petitioner believes that all three of these casks would be easily breached and deeply penetrated by an attack utilizing the reference antitank weapon and by most of the military weapons and commercial explosives previously discussed. Petitioner further believes that all three of these casks could be completely perforated by an attack utilizing the Milan or TOW antitank weapons. Moreover, the new rail cask designs differ from the casks assumed in previous DOE and NRC radiological sabotage consequence assessments in the use of polypropylene neutron shields versus steel shelled water jackets. The elimination of the water jackets could result in a larger release of respirable particulates.

Petitioner believes that a successful terrorist attack using large antitank missiles, such as the Milan or TOW, or sufficient hand-carried quantities of commercial shaped charge explosives, against a GA-4 truck cask, would cause a release of radioactive materials at least equal to the one percent release demonstrated in the SANDIA full-scale test. A one percent release from a GA-4 cask loaded with reference 10-year cooled SNF would involve a source term of more than 8,000 curies, with fission products such as Sr-90, Cs-134, and Cs-137 constituting over a third of the total curies, and transuranic such as Pu-241 could constitute twenty percent or more. A one percent release from a large rail cask similarly loaded could involve more than 40,000 curies. Attachment A at 68-9. Petitioner is further concerned that a successful attack, especially on a GA-4 truck cask, could have far greater radiological consequences than those calculated in previous assessments due to: (1) a potentially larger percentage release of SNF; (2) a potentially higher percentage of respirable particulates and/or vaporized radionuclides; and (3) potentially more widespread dispersal and deposition because of complete cask body perforation, accompanying use of an incendiary device or multiple high-energy explosive devices, and a potential accompanying fire from combustion of the transport vehicle fuel supply or another fuel source. Petitioner requests that the Commission specifically consider these issues in rulemaking supported by a new consequence assessment.

B. Need for a Comprehensive Consequence Assessment

As documented in the foregoing sections of this petition, Petitioner Nevada is requesting that the Commission completely reexamine the issue of terrorism and sabotage against spent nuclear fuel and high-level radioactive waste shipments, in order to determine the adequacy of the current physical protection regulations under 10 C.F.R. 73, and in order to assist the DOE and the affected stakeholders in the preparation of a legally sufficient environmental impact statement as part of the NRC licensing process for a geologic repository or an interim storage facility. To accomplish this, the Commission should conduct a comprehensive assessment of the consequences of three types of attacks which have the potential for radiological sabotage: attacks against transportation infrastructure used by nuclear waste shipments, attacks involving capture of a nuclear waste shipment and use of high energy explosives against the cask, and direct attacks upon a nuclear waste shipping cask using antitank missiles. The consequence assessment for repository shipments should be based on program-specific and location-specific assumptions as outlined in Attachment A at 49-71, and should address the full range of impacts of a terrorism/sabotage event resulting in a release of radioactive materials: immediate and long-term implications for public health; environmental impacts, broadly defined; standard socioeconomic impacts, including cleanup and disposal costs and opportunity costs to affected individuals and business; and so-called special socioeconomic impacts, including individual and collective psychological trauma, and economic losses resulting from public perceptions of risk and stigma effects.

As part of its comprehensive reexamination of terrorism/sabotage consequences, the Commission should engage an independent technical organization with appropriate expertise to advise the Commission on two critical issues: (a) the need for physical testing, full-scale and/or scale model, to evaluate weapons capabilities, cask vulnerability to attack with high-energy explosive devices, and the response of spent nuclear fuel to such attacks (specifically, to determine fuel mass release from a cask, particle size distribution of released fuel, and special concerns associated with volatile radionuclides such as Cs-134 and Cs-137); and (b) the appropriateness of existing computer models for evaluating near-site environmental dispersion of released radionuclides, resulting health effects, cleanup and disposal requirements, and economic costs.

The Commission should conduct its comprehensive reassessment of terrorism/sabotage consequences in a forum conducive to meaningful participation by all affected stakeholders. Commission should consider creation of a stakeholder advisory group to assist the Commission in this task.

The Commission should publish a full report on all unclassified findings of its consequence reassessment, regardless of whether the Commission determines that modifications are necessary to the physical protection regulations. The Commission should specifically avoid the approach followed in the 1984 proposed rulemaking, where stakeholders and the general public were never advised of the Commission's findings and conclusions.

As part of the comprehensive reassessment, the Commission should reevaluate the current definition of radiological sabotage used for determining inclusion of events in the Safeguards Summary Event List. Current practice apparently results in the omission of at least some potential threats from this important risk assessment and risk management data base.

IV. CONCLUSION

Based on the foregoing petition, Petitioner State of Nevada respectfully requests that the Commission exercise its relemaking authority pursuant to 10 C.F.R. 2.800-2.804, by amending specific regulations enumerated herein governing safeguards for shipments of spent nuclear fuel against sabotage and terrorism. Further, Petitioner State of Nevada petitions the Commission to conduct a comprehensive assessment of the consequences of terrorist attacks that have the capability of radiological sabotage.

Petitioner submits that the foregoing regulatory amendments and the need for a comprehensive assessment are necessitated by changes in the nature of the terrorist threat and increased vulnerability of shipping casks to terrorist attacks involving high-energy explosive devices as set forth in the petition. In the interest of safeguarding the public health, safety and welfare, the State of Nevada urges the Commission to undertake the tasks outlined in the petition.

Dated this 22nd day of June, 1999.

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NUCLEAR WASTE TRANSPORTATION SECURITY AND SAFETY ISSUES

The Risk of Terrorism and Sabotage Against Repository Shipments

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This report was prepared for:

The Nevada Agency for Nuclear Projects
Capitol Complex
Carson City, Nevada 89710

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LIST OF ABBREVIATIONS

BMI	Battelle Memorial Institute
BRL	U.S. Army Ballistics Research Laboratory
BWR	Boiling Water Reactor
CFR	Code of Federal Regulations
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
FBI	Federal Bureau of Investigation
GA 4	General Atomics Truck Cask (Capacity 4 PWR Assemblies)
GA 9	General Atomics Truck Cask (Capacity 9 BWR Assemblies)
HED	High Energy Device (explosive)
HHT	Heavy Haul Truck
HLW	High-Level Radioactive Waste
ISF	Interim Storage Facility
LLEA	Local Law Enforcement Agencies
LWT	Legal-Weight Truck
MPC	Multi-Purpose Canister
MTIHM	Metric Tons Initial Heavy Metal
MTU	Metric Tons Uranium
MWR	Mountain West Research
NAC	Nuclear Assurance Corporation
NAC LWT	Nuclear Assurance Corporation Legal-Weight Truck Cask
NAC-TSC	Nuclear Assurance Corporation Storage/Transport Cask (Rail)
NANP	Nevada Agency for Nuclear Projects
NDOT	Nevada Department of Transportation
NRC	U.S. Nuclear Regulatory Commission
NSP	Northern States Power Company
NTS	Nevada Test Site

NWPO	**Nevada Nuclear Waste Project Office**
ORNL	**Oak Ridge National Laboratories**
PIC	**Planning Information Corporation**
PWR	**Pressurized Water Reactor**
SNF	**Spent Nuclear Fuel**
SNL	**Sandia National Laboratories**
SSEL	**Safeguards Summary Event List**
TNA	**Transportation Needs Assessment**
UNLV TRC	**University of Nevada, Las Vegas Transportation Research Center**
UP	**Union Pacific Railroad**
YM	**Yucca Mountain, Nevada**

EXECUTIVE SUMMARY

The U.S. Senate debate on the Nuclear Waste Policy Act of 1996 (S. 1936) in July, 1996, reopened the public controversy over the risk of terrorism and sabotage against spent nuclear fuel shipments. This issue last received widespread public attention in the mid-1980s when the Nuclear Regulatory Commission (NRC) proposed reducing the physical protection regulations designed to safeguard shipments from terrorist attack. Senate action brought a new sense of urgency to the terrorism issue, since cross-country shipments to the proposed interim storage facility in Nevada could have begun as early as 1999, compared to a start date of about 2010 for shipments to a repository under current U.S. Department of Energy (DOE) plans.

The purpose of this report is to reexamine the risks of terrorism and sabotage against nuclear waste shipments in light of developments that have occurred since the NRC last publicly addressed these issues in 1984. We begin with an overview of the radiological characteristics of spent nuclear fuel and the risks associated with spent fuel transportation. We examine the outlook for shipments of spent nuclear fuel and high-level radioactive waste to a repository or storage facility in Nevada. We review and critique the NRC's assessment of the consequences of a successful terrorist attack on a spent fuel shipping cask. We suggest an alternative approach to terrorism risk assessment, recommend new assumptions for assessing the consequences of terrorist attacks using high-energy explosive devices, and conclude with specific recommendations for actions by the NRC, DOE, and the State of Nevada.

Nuclear Waste Transportation Risks

The risks associated with transporting spent nuclear fuel (SNF) and high-level radioactive waste (HLW) to a repository or centralized storage facility result from the large number of cross-country shipments required, the highly radioactive nature of the cargo, and the potentially devastating consequences of a very severe transportation accident or successful terrorist attack. Public perception of these risks is an additional consideration in terrorism risk assessment. The well documented public dread of nuclear waste transportation could be a significant consideration in the selection of a nuclear waste shipment as a target for terrorist attack.

Outlook for Shipments to Nevada

A report prepared by Planning Information Corporation (PIC) for the Nevada Agency for Nuclear Projects (NANP) projects nuclear waste shipments to Nevada for two scenarios: a repository at Yucca Mountain opening in the year 2010, the current DOE plan; and a storage facility at the Nevada Test Site (NTS) opening in 1999, as proposed in S. 1936. The repository-only scenario, assuming heavy reliance on rail, construction of a new rail spur, and use of high-capacity casks, results in approximately 18,400 shipments over 30 years. The NTS storage scenario, assuming intermodal transfers at Caliente, Nevada and much heavier reliance on trucks, results in 56,600 to 104,500 total shipments over about 40 years. The lower number would occur if market conditions are favorable for the rapid deployment of a large fleet of GA4/9 casks or their equivalent and if DOE chooses to pursue lower shipment numbers as a matter of policy.

PIC also identified the most likely cross-country routes to Nevada for two scenarios. Assuming that Nevada does not designate alternative routes and that DOE contract motor carriers follow the quickest routes consist with federal regulations, the primary east-west highway corridors would be I-80 from Chicago, I-70 from St. Louis, and I-15 from Salt Lake City. The primary rail corridor would be the Union Pacific mainlines out of Kansas City and Chicago, through Cheyenne and Salt Lake City. PIC also identified alternative southern routes that would minimize winter weather disruptions, avoid highway tunnels in Colorado, and reflect recent rail industry mergers and acquisitions. PIC concluded that alternative routes like I-40 from Nashville, Tennessee to Barstow, California, could be the primary east-west highway corridor and that the Santa Fe-Burlington Northern line from Kansas City to San Bernadino could be the primary east-west rail corridor.

Shipment Characteristics Relevant to Terrorism Risk Assessment

NANP staff and contractors have used the PIC report to identify projected shipment routes and characteristics relevant to terrorism risk assessment. Factors potentially advantageous to attackers and disadvantageous to law enforcement and emergency response personnel include multiple transport modes and routes, long distance shipments (average length greater than 2,000 miles), daily shipments (as many as 3 to 9 cask-shipments per day), routes through highly populated areas, routes that place shipments in tactically disadvantageous positions, routes with marginal safety design features, routes with limited rest and refueling locations, and routes with a low likelihood of swift local law enforcement agency response. NANP staff and contractors have identified highly vulnerable route segments in Nevada including: I-15 and US 95 through downtown Las Vegas, especially the intersection known locally as the "Spaghetti Bowl;" the Union Pacific (UP) mainline through downtown Las Vegas, and tunnels along the UP between Uvada and Elgin; and steep grades to and from mountain passes along US 93, State Route 375, and US 6, the proposed heavy haul truck route between Caliente and Tonopah.

Previous Assessments of Terrorist Attack Consequences

NRC contractor reports prepared in the late 1970s estimated that sabotage of a spent fuel shipment in an urban area could result in hundreds of early fatalities, thousands of latent cancer fatalities, and economic losses in the billions of dollars. NRC responded to these risk assessments by issuing interim physical protection requirements for spent fuel shipments in July, 1979, followed by amended rules, 10 CFR 73.37(a) through (e), effective July 3, 1980, that required advance notification of the NRC, procedures for coping with safeguards threats and emergencies, designation of heavily populated areas, instructions to escorts (including use of deadly force by armed escorts in heavily populated areas), establishment of a communications center, maintenance of shipment logs, arrangements with local law enforcement agencies, advance route approval by NRC, avoidance of intermediate stops, procedures for stops, escort training requirements, and periodic contacts with the communications center

Concurrent with issuance of the new safeguards regulations, NRC and DOE sponsored further research on the consequences of terrorist attacks. These studies included scale-model and full-scale tests at Sandia National Laboratories and Battelle Memorial Institute to determine the effects on shipping casks of attacks involving high energy explosive devices. These studies demonstrated that terrorists using military explosives could blow a 6-inch hole in the cask wall, penetrate the cask deeply, and disperse one percent of the fuel mass to the environment. Since only a tiny fraction of the fuel was released in respirable form, NRC concluded that the health effects of a successful attack would be far less than previously estimated (no early fatalities and less than 7 latent cancer fatalities even if the attack took place in New York City under worst case conditions). As a result of these tests, NRC concluded that the safeguards regulations could be reduced. NRC proposed a reduction in regulatory safeguards in 1984 and solicited public comments, many of which were highly critical of the NRC's technical analysis and rulemaking proposal. With no public explanation, the NRC allowed the proposed rule to lapse in 1987, ignoring the technical criticisms raised by the U.S. Army Ballistics Research Laboratory and other reviewers. NRC and nuclear industry representatives have continued to cite the Sandia and Battelle reports as evidence that terrorist attacks pose only a minimal threat to nuclear waste shipments.

DOE adopted these questionable research findings in the 1986 Environmental Assessment for the Yucca Mountain repository site: "Though transportation packagings have not been specifically designed to mitigate the consequences of a sabotage event, they have been shown experimentally to limit to low levels the potential adverse health consequences to the public. Predictions based on releases experimentally determined in both DOE and NRC studies indicate no immediate radiation-induced deaths and a small number of latent cancer fatalities would be expected even in a very densely populated area (Sandoval et al., 1983). To create the level of hazard encountered in the experiments, such sabotage attempts would have to be performed by trained experts, and precise placement of the explosives in the most vulnerable positions would be necessary."

The NRC's 1984 terrorism assessment is fundamentally flawed because it fails to fully evaluate the consequences of the total amount of spent fuel released to the environment by a terrorist attack using explosives. Neither logic nor evidence support the NRC's contention that the "consequences of an act of sabotage would be a direct function of the quantity of spent fuel that would be released in respirable form [particles having a diameter of less than four microns]." The Sandia full-scale test may or may not have represented a worst case attack, but it did demonstrate that a successful attack using a less than optimal weapon could disperse 1% of the cask contents (more than five pounds of spent fuel fragments) from a truck cask containing one irradiated PWR assembly. The NRC health effects analysis considered only the fraction of an ounce of material released as a respirable aerosol and ignored the human health, environmental, social, and economic consequences of the total release, certainly in excess of 2,000 curies, and the intense gamma and neutron radiation emitted from the damaged cask. Even if the blast damage and contamination zone were confined to an area within 100 meters distance (an area of about 8 acres), the consequences of such an attack in a highly populated urban area certainly deserve a more thorough assessment than that conducted by the NRC and its contractors.

The NRC analysis was deficient in other respects. First, the NRC failed to consider the social and psychological impacts of a successful terrorist attack. Second, the NRC failed to consider the standard economic impacts including business losses and cleanup and disposal costs. Third, the NRC failed to consider the potentially enormous economic losses resulting from stigma effects and perceived risks. Finally, the choice of cask, reference weapon, and mode of attack assumed by Sandia and Battelle did not represent a credible worst case scenario in the early 1980s and are even less representative today.

Preferred Approach to Assessing the Risks of Terrorism and Sabotage Against Repository Shipments

Events since 1984, especially the increasing lethality of terrorist attacks in the United States, argue for a new, more comprehensive assessment of the risk of terrorism and sabotage against repository shipments. At the same time, changes in spent nuclear fuel shipping cask designs and improvements in the capabilities of weapons available to potential adversaries make the NRC's 1984 terrorism assessment increasingly irrelevant.

A comprehensive assessments should, at a minimum, evaluate potential consequences and impacts of three types of actions: (1) actions to disrupt shipments without causing damage to the cask; (2) actions to induce severe accidents, possibly causing damage to the cask and release of contents; and

(3) attacks on shipping casks that are clearly intended to cause a significant release of radioactive materials.

The willingness of terrorists to kill or injure large numbers of Americans, demonstrated in the World Trade Center and Oklahoma City bombings, compels any current assessment to focus on incidents that are clearly intended to cause, or could cause, radiological sabotage. The FBI's Terrorism in the United States: 1995 reported: "In the past year, the country witnessed the re-emergence of spectacular terrorism with the Oklahoma City bombing. Large-scale attacks designed to inflict mass casualties appear to be a new terrorist method in the United States." The Oklahoma City bombing reflected a "general trend in which fewer attacks are occurring in the United States, but individual attacks are becoming more deadly."

Actions to induce severe accidents. A comprehensive terrorism/sabotage risk assessment must consider that: transportation infrastructure used by spent nuclear fuel shipments could be attacked by a range of adversaries including antinuclear activists, political terrorists, and transportation industry personnel; that rail and/or highway infrastructure could be targeted; and that attacks could occur at urban and/or rural locations.

Lessons learned from previous incidents of sabotage against passenger trains and highway infrastructure, particularly insights into the intentions and capabilities of the attackers, must be applied to the assessment of potential attacks on infrastructure used by nuclear waste shipments. These lessons include: (1) attacks on trains, bridges, and tunnels without warning that show a willingness if not an intention to kill, maim, and terrify tens, hundreds, or thousands of people at a time; (2) the attackers technical expertise, at least in the case of the rail sabotage events, has been sufficient to defeat existing technical countermeasures, such as electronic warning systems; (3) the attackers success in causing accident conditions such as derailments at speeds of 50-60 miles per hour, followed by 30 foot drops, demonstrates their ability to at least challenge the containment performance standards of NRC-certified shipping containers; and (4) future attacks on infrastructure may be carried out with use of home-made explosives and do not require the procurement of exotic weapons to be successful.

A comprehensive terrorism/sabotage risk assessment must consider a range of responses by the cask and its contents to the forces generated by an attack on transportation infrastructure components. Such a comprehensive assessment is difficult because of the absence of full-scale physical test results for the new cask designs that will be used for repository shipments. Under such conditions as hypothesized above, there may be no significant likelihood of a loss of cask shielding or containment. For example, the simple derailment of a single rail cask car, even at a maximum normal operating speed of 50 to 70 miles per hour, would probably not result in a significant radiological exposure or release of contents, absent unexpected human factors.

On the other hand, high-speed derailment of a rail cask car or cars could result in a significant radiological exposure or release of contents if coupled with other dangerous conditions, such as collision with a massive rock face or outcrop, collision of the cask side midpoint against a bridge support column, fall from a high bridge or trestle, tumble down a steep canyon wall, or rupture of a collocated petroleum or natural gas pipeline. The derailment and pile-up of a dedicated train could subject a cask to considerable impact and crush forces from the locomotives and other casks. In addition, supplemental attack tactics like the use of explosives to create a boulder slide or collapse a rail tunnel could also subject casks to severe crush forces.

Attacks on shipping casks. A comprehensive terrorism/sabotage risk assessment must consider direct attacks on casks with a range of high-energy explosive devices, with and without capture of the cask, by a range of potential adversaries with widely differing objectives and capabilities. Adversaries capable of capturing and controlling the cask and transport vehicle could attack the cask with a variety of devices, including military demolition charges, commercial conical shaped charges, commercial cutting charges, or a massive diesel fuel and fertilizer truck bomb. Attackers may well be able to control the cask for a period of 30 to 120 minutes, for example, by threatening to kill the driver, train crew, escorts, or other hostages. Given sufficient time, the attackers may be able to increase the effectiveness of their weapons, for example, by removing an impact limiter and applying explosives directly to the cask closure lid, by removing the personnel barrier and applying explosives around the middle of the cask, or by applying multiple charges at different points.

Adversaries could use a variety of weapons to attack a cask without the necessity of capturing it. Remote-controlled or self-detonating mines could be used against either truck or rail shipments. Man-portable mortars, rifle-fired grenades, recoilless guns, and a variety of anti-tank missiles could be used to attack shipments while in transit, in some cases from a distance of hundreds or thousands of meters. It is also conceivable that adversaries could obtain and use military aircraft or attack vehicles armed with bombs, missiles, cannons, or other powerful weapons. The risk of attacks involving stolen or otherwise diverted military weapons systems must be given special attention considering the number and nature of military installations in Nevada and along the transportation corridors to Nevada.

A number of different adversary profiles must be considered. Potential perpetrators include domestic and foreign political terrorist groups and individuals, radical antinuclear activists, disgruntled nuclear or transportation industry employees, organized criminal enterprises, and foreign governments. The individuals actually carrying out attacks may have much greater technical expertise than assumed by those compiling their profiles. The attackers may very well be current or former military or civilian explosives experts. During wartime, declared or undeclared, the attackers could be enemy military personnel or specially trained agents. A comprehensive assessment should test different combinations of weapons capabilities and attacker capabilities and objectives because each combination could result in greater or lesser consequences.

A sufficient repository transportation risk assessment must, at a minimum, consider two scenarios: an attack in which the cask is captured, penetrated by one or more explosive devices, and releases a significant amount (at least one percent) of its radioactive contents; and an attack in which the cask is perforated by one or more armor-piercing rockets or missiles and releases a significant amount (at least one percent) of its radioactive contents.

Guidelines for Assessing the Consequences of Terrorist Attacks Employing Anti-tank Weapons
The consequences of a successful terrorist attack involving armor-piercing weapons or other high energy explosive devices will constitute one of the most important components of a comprehensive assessment of the risk of terrorism against repository shipments. A new consequence assessment is necessary because the assessments conducted by DOE and NRC contractors in the late 1970s and early 1980s are methodologically deficient and based on assumptions that do not accurately represent the types of shipments likely to be made to a repository (or storage facility) in the first decade of the 21st century and the threats those shipments will face.

A meaningful terrorism consequence assessment must employ assumptions consistent with information about the weapons currently available, and weapons likely to become available, to potential adversaries and the technical and tactical expertise of potential adversaries. It must employ assumptions consistent with current DOE spent fuel and high-level waste transportation plans, particularly as those plans determine the characteristics of the shipping casks that will be used and the characteristics of the spent fuel shipped. In order to be legally sufficient for purposes of the Yucca Mountain Environmental Impact Statement, a new and comprehensive terrorism consequence assessment must employ credible worst case assumptions about the timing and location of a potential attack, weather conditions during and after the attack, and other assumptions consistent with the actual characteristics of the routes most likely to be used for shipments to a repository or storage site in Nevada.

Portable anti-tank missiles should be the reference weapon for the following reasons: munitions, range, and availability. First and foremost, virtually all of the available anti-tank rockets and missiles have warheads capable of completely perforating a truck cask and its spent fuel cargo and are capable of deeply penetrating (if not completely perforating) a rail cask and damaging the spent fuel inside. These weapons are designed to hit moving targets at a distance of 30 meters or more, eliminating the need to capture the cask, and facilitating selection of optimal attack times and locations. Portability of these weapons allows further flexibility in attack planning, including use of multiple warheads, and in escape planning. Many different types of anti-tank missiles are currently being produced in many different countries and, in some instances, tens to hundreds of thousands of units of particular designs have been produced. Most older weapons have been used in battle, and newer versions have been extensively field tested. The limitations and deficiencies of specific weapons (backblast effects, operator error in guidance control, guidance system failure, fuse and warhead failure) are known and can be factored into the consequence assessment. Potential adversaries could obtain anti-tank weapons through a variety of channels, including terrorist state-sponsorship, purchase, theft, or blackmail.

A new consequence assessment should evaluate a terrorist attack using anti-tank weapons at least equal to current versions of the U.S. TOW and French Milan missiles. For purposes of scenario development, the reference weapon should be assumed to be man-portable, operated by one to three persons, capable of firing up to three missiles, with a minimum range of 75 meters and a maximum range of 2,000. The reference weapon should be assumed capable of penetrating 40 inches or more of armor plate steel with a hole diameter of 3 to 6 inches. Based on U.S. Army experience with the TOW, a hit-probability of 90 percent or greater should be assumed.

A future-oriented risk assessment must acknowledge that the shipping casks used for repository shipments will have different design configurations and use different structural and shielding materials than the casks that were assumed in the DOE and NRC consequence assessments. Some of these differences may make them more vulnerable to attack with armor-piercing weapons or high-energy explosives. The new casks will also have significantly larger payloads, resulting in larger source term amounts available for release even when loaded with ten-year old spent fuel.

The GA 4 cask should be used as the reference truck shipment target. The NAC-TSC should be used as the reference rail shipment target. With side-to-side widths of 37 inches and 96 inches, respectively, the GA 4 and the NAC-TSC appear to represent the softest targets among the new casks designed to transport PWR SNF, the predominant waste type in the projected repository inventory. The GA 4 truck cask design has nearly completed the NRC certification process. The NAC-TSC has completed the NRC certification process.

The spent fuel shipped to a repository or centralized storage facility will have different radiological and physical characteristics and will be shipped in larger quantities per cask than was assumed in the DOE and NRC consequence assessments. The spent fuel radionuclide inventory (calculated according to initial enrichment, burnup, and cooling time) and the quantity of spent fuel (weight and number of assemblies) per package determine the total amount of radioactivity (the source term) that could be released in a terrorist attack. The physical characteristics of the spent fuel and its response to blast impact and heat, particularly the fracture characteristics and the size distribution of particles, determine the potential amount of radioactive materials released from the cask, their dispersion, health and environmental impacts, and cleanup requirements.

The reference spent fuel for terrorism consequence assessment should be a 10-year-cooled, medium-high burnup, Westinghouse PWR assembly. A GA 4 truck cask loaded with 4 assemblies of the reference fuel would represent a total radioactivity of about 850,000 curies. A NAC-TSC rail cask loaded with 26 assemblies of the reference fuel would represent a total radioactivity of about 5.5 million curies. In either case, but especially in the case of the large rail cask, a terrorist incident resulting in a one percent release of cask contents would have radiological consequences far greater than those assumed in the outdated DOE and NRC consequence assessments.

For purposes of the Yucca Mountain Environmental Impact Statement, a new and comprehensive terrorism consequence assessment must employ credible worst case assumptions about the timing and location of a potential attack and weather conditions during and after the attack, consistent with characteristics of the routes most likely to be used for shipments to a repository or storage site in Nevada.

Combinations of location, timing, and weather conditions are important determinants of impacts on public health and safety, environmental quality, business activities, and property values. These factors determine the number of people initially exposed to incident consequences, the nature and duration of exposure to incident consequences (especially exposure to released radionuclides), and the timing and effectiveness of emergency response activities.

Given current routing assumptions, the consequence assessment should evaluate an attack on a truck or rail shipment at an urban location in metropolitan Clark County. The assessment should assume that the attack occurs during heavy evening commuter traffic congestion or during a nighttime special event. Credible severe weather scenarios for Clark County include a 12 hour period of sustained winds in excess of 30 miles per hour and 6 or more inches of rain during a 24 hour period. Immediate special concerns would be the evacuation of as many as several hundred thousand visitors and residents and the potential contamination of hotel, resort, and casino properties worth billions of dollars.

The consequence assessment should also evaluate an attack on a rail shipment at a rural location between Las Vegas and the Utah-Nevada state line. The assessment should assume that the attack occurs at a time when emergency response would be slowed or delayed by other events or limited personnel, for example during a weekend or on a major holiday. The assessment should assume worst-case weather conditions appropriate for the postulated attack location. If the attack occurred along a route segment subject to flash flooding, a credible severe weather scenario would be 6 or more inches of rain during 24 hours. Immediate special concerns, depending upon the postulated location of the attack, could include contamination of Indian reservation lands, private residences, agricultural lands, and Lake Mead (a major recreational resource and water supply source for Arizona, California, and Nevada).

Recommendations to the NRC, DOE , and the State of Nevada

The NRC should completely reexamine the issue of terrorism and sabotage against spent nuclear fuel and high-level radioactive waste shipments, in order to determine the adequacy of the current physical protection regulations under 10 CFR 73 and in order to assist the DOE and the affected stakeholders in the preparation of a legally sufficient environmental impact statement as part of the NRC licensing process for a geologic repository or an interim storage facility.

The NRC should conduct a comprehensive assessment of the consequences of three types of attacks that have the potential for radiological sabotage: attacks against transportation infrastructure used by nuclear waste shipments; attacks involving capture of a nuclear waste shipment and use of high energy explosives against the cask; and direct attacks upon a nuclear waste shipping cask using anti-tank missiles.

The NRC should engage an independent technical organization with appropriate expertise to advise the Commission on: the need for physical testing, full-scale and/or scale model, to evaluate weapons capabilities, cask vulnerability to high-energy explosive devices, and the response of spent nuclear fuel; and the appropriateness of existing computer models for evaluating near-site environmental dispersion of released radionuclides, resulting health effects, cleanup and disposal requirements, and economic costs.

The NRC should conduct its comprehensive reassessment of terrorism/sabotage consequences in a forum conducive to meaningful participation by all affected stakeholders. NRC should consider the creation of a stakeholder advisory group to assist the NRC in this task.

The NRC should publish a full report on all unclassified findings of its consequence reassessment, regardless of whether the Commission determines that modifications are necessary to the physical protection regulations.

The NRC should reevaluate the current definition of radiological sabotage in the Safeguards Summary Event List.

DOE should evaluate the impacts of terrorism and sabotage against spent fuel and nuclear waste shipments in the Yucca Mountain repository environmental impact statement (EIS) and in any EIS prepared for an interim storage facility. The impacts of a terrorism/sabotage event resulting in a release of radioactive materials include: immediate and long term public health effects; environmental impacts, broadly defined; standard socioeconomic impacts, including cleanup and disposal costs and opportunity costs to affected individuals and businesses; and so-called special socioeconomic impacts, including economic losses resulting from perceptions of risk and stigma effects.

DOE should incorporate terrorism/sabotage risk management and countermeasures in all DOE transportation plans and contracts relating to operation of a repository, interim storage facility, and/or intermodal transfer facility.

DOE should prepare a comprehensive report on the liability for costs and damages resulting from terrorism/sabotage against nuclear waste shipments under the Price Anderson liability system and private nuclear insurance coverage.

The State of Nevada should participate in any NRC terrorism/sabotage consequence assessment and/or rulemaking proposal and should continue to address terrorism/sabotage issues as part of its oversight of DOE site characterization activities, EIS preparation, and transportation planning.

The State of Nevada should, as part of its oversight of DOE activities, address Nevada-specific issues such as State and local enforcement agencies preparedness for terrorism/sabotage incidents; impacts of terrorism/sabotage incidents on rural communities, including outmigration; and impacts on Native American communities.

The State of Nevada should, as part of its oversight of DOE activities, continue to address larger transportation terrorism/sabotage issues, such as the comparative vulnerability of at-reactor storage versus shipment to and storage/disposal at centralized facilities and consequences of attacks on infrastructure and shipping casks.

INTRODUCTION

On July 31, 1996, the U.S. Senate debated the Nuclear Waste Policy Act of 1996 (S. 1936), a bill sponsored by Senators Craig, Johnston, and Murkowski. S.1936 proposed that the U.S. Department of Energy (DOE) construct and operate an interim storage facility for spent nuclear fuel and high-level radioactive wastes at the Nevada Test Site, while continuing studies to determine the suitability of the nearby Yucca Mountain site for a permanent geologic repository. One of the most contentious portions of this debate addressed the risks of terrorist attacks on spent fuel and nuclear waste shipments to Nevada, shipments that could begin as early as 1999 under the provisions of S. 1936. Perhaps the most extraordinary aspect of this debate was that both the proponents and the opponents of the bill agreed that terrorists could breach a spent fuel shipping cask with high energy explosives or anti-tank weapons, resulting in a release of highly radioactive materials. The major point of disagreement was over the consequences of a successful terrorist attack.[Ref. 1] The Senate debate reopened a controversy that had last received widespread public attention in the mid-1980s when the Nuclear Regulatory Commission (NRC) proposed reducing the security regulations designed to protect spent nuclear fuel shipments from terrorist attack.

This report begins with an overview of the radiological characteristics of spent nuclear fuel and the risks associated with spent fuel transportation. We examine the outlook for spent fuel and high-level nuclear waste shipments to Nevada for two scenarios: a repository beginning operations in 2000; and an interim storage facility beginning operations in 1999. We then review and critique the NRC's assessment of the consequences of a successful terrorist attack on a spent fuel shipping cask. We suggest an alternative approach to terrorism risk assessment, recommend new assumptions for assessing the consequences of terrorist attacks using high energy explosives, and conclude with specific recommendations for actions by the State of Nevada, the DOE, and the NRC

NUCLEAR WASTE TRANSPORTATION RISKS

While there have been several potentially serious accidents involving spent fuel shipments, there have been no radioactive releases since the early 1960s and no radiological injuries or deaths. Why then should nuclear waste transportation risks receive such special attention compared to other hazardous materials shipments? The answer is found by examining the potential near-term increase in the number of shipments, major changes in the nature of the shipments, the radiological characteristics of spent fuel, and the potential consequences of transportation incidents and accidents involving spent fuel.

During the past decade and a half, nuclear utilities and research facilities in the United States have made relatively few shipments of irradiated reactor fuel, more commonly referred to as spent nuclear fuel (SNF). According to the NRC, nuclear utilities and research facilities made 1,306 shipments containing 1,335 MTU (metric tons uranium) of SNF between 1979 and 1995.[Ref. 3] During the same period, DOE made several hundred shipments of naval reactor and foreign research reactor SNF and several dozen shipments of SNF from commercial reactors and reactor core debris from Three Mile Island to DOE facilities in Idaho and South Carolina. The DOE shipments were not regulated by NRC and are therefore not included in the NRC data presented in Table 1.

Table 1

U.S. Spent Nuclear Fuel Shipments, 1979 - 1995

- Amount Shipped: 1,335 MTU (79 MTU/year)
- Total Shipments: 1,306 (77 Shipments/year)
- Truck Share of Shipments: 89%
- Rail Share of MTU: 75%
- Average Rail Shipment Distance: 346 miles (79% less than 500 miles)
- Average Truck Shipment distance: 678 miles (82% less 900 miles)

Source: Reference 3

DOE currently plans to begin shipping SNF from nuclear power plants to a geologic repository about the year 2010. Legislation pending in Congress could start SNF shipments as early as 1999 or 2000. Each and every year, for three or four decades, DOE will ship more highly radioactive waste and spent nuclear fuel, and make more shipments, than the entire U.S. nuclear industry has shipped in the past two decades. The average distance for rail shipments will increase six times, and truck shipments will be three times longer than in the past. These dramatic increases in the number and length of future shipments challenge the relevancy of the nuclear industry's past safety record. In particular, the longer distances will create additional opportunities for equipment failure and human error and additional exposure to accidents caused by other vehicles, by infrastructure failures, and by bad weather.

Spent fuel from commercial nuclear reactors is expected to make up about 90 percent of all the material shipped to the repository or storage facility. Figure 1 shows a typical commercial fuel rod and fuel assembly. Because there are dozens of different fuel assembly designs, and since each batch of irradiated fuel has somewhat different radiological characteristics, DOE has designated "reference" fuel assemblies for system planning purposes. About two-thirds of the SNF will come from pressurized water reactors (PWRs), with the remainder coming mostly from boiling water reactors (BWRs). The "reference" PWR assembly is about 13 feet long, 8.5 inches wide and deep, and holds almost 300 long, thin rods filled with fuel pellets containing 0.46 metric tons of uranium (MTU). The "reference" boiling water reactor (BWR) assembly has a somewhat different configuration and contains less uranium fuel (0.19 MTU).[Ref. 2]

The shipping casks currently in use require different fuel baskets for different types of SNF. New cask designs may have separate versions for PWR and BWR shipments. Truck casks similar to that shown in Figure 2 have been used for the majority of SNF shipments in the United States. Since rail casks have larger payloads, most of the SNF, when measured by weight, was actually shipped in rail casks similar to that shown in Figure 3.

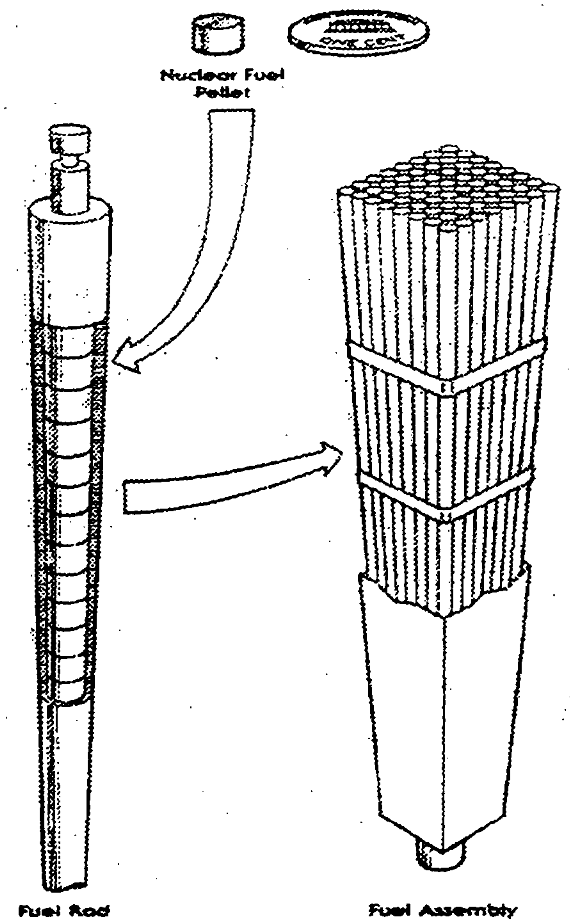


Figure 1. Nuclear Reactor Fuel Rod and Assembly

Note that loaded casks mounted on truck trailers or rail cars are usually covered by a personnel barrier which conceals the distinctive shape of the SNF casks. Federal regulations require a placard outside the personnel barrier that clearly identifies the material being shipped. Current generation shipping casks could, and probably will, be used for some shipments to a repository or interim storage facility, especially during the first decade of operations. The majority of repository shipments are expected to use new, high-capacity casks that carry four or five times larger payloads. The new cask designs have major implications for terrorism risk assessment, which will be discussed later in this report.

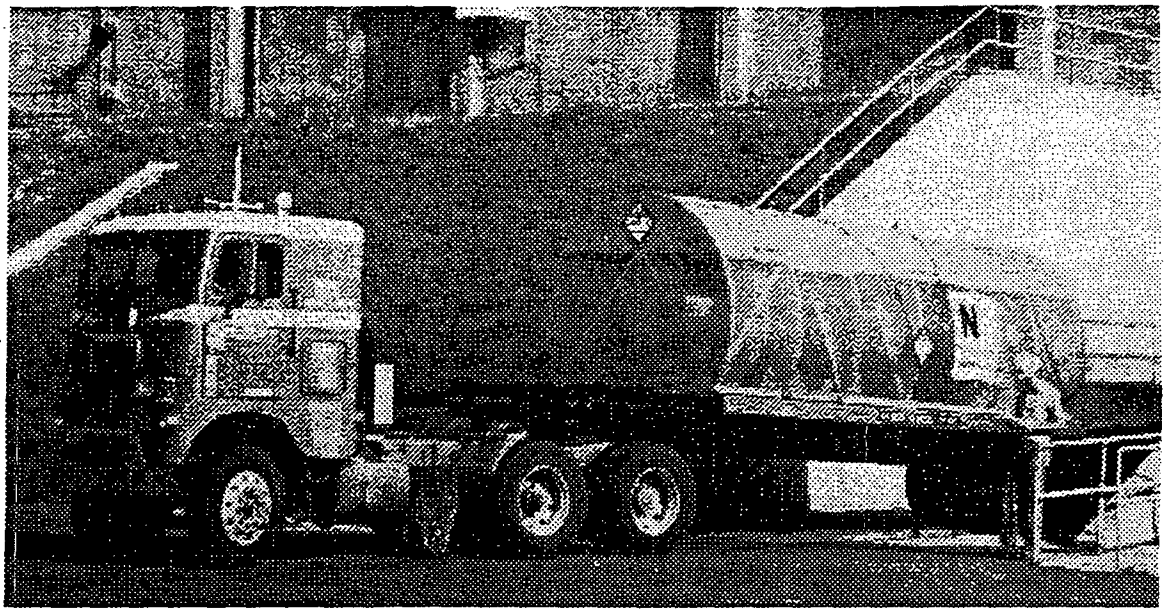


Figure 2. Current Generation Truck Spent Fuel Shipping Cask

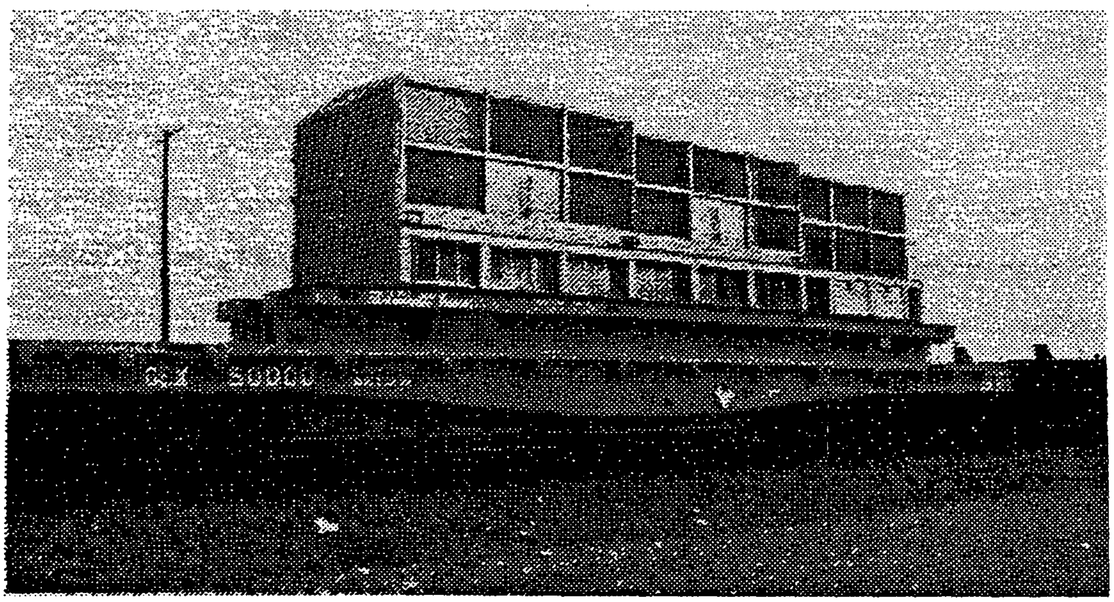


Figure 3. Current Generation Rail Spent Fuel Shipping Cask

Fuel assembly and cask design differences aside, all of the spent fuel shipped to a federal storage or disposal facility will be highly radioactive for thousands of years and thermally hot for hundreds of years. Nuclear fission inside the reactor transforms some of the original uranium fuel into other uranium isotopes, isotopes of plutonium and other transuranic elements, and fission products such as strontium-90 and cesium-137. Fission products account for most of the radioactivity in spent fuel for the first hundred years after removal from the reactor and are the major source of radiological concern during storage and transportation operations. Fission products, which emit both beta and gamma radiation, are the primary sources of exposure during routine operations and the major potential source of irradiation and contamination in the event of an accident or terrorist attack that breaches the cask. [Ref. 2]

DOE plans assume that spent fuel will be cooled in storage at reactors for ten years on average before shipment to a repository. SNF shipped to an interim storage facility (ISF) could be cooled as little as five years. Table 2 summarizes the two most important radiological characteristics of SNF for assessing transportation risks, total activity and surface dose rate, as a function of cooling time or age. Even after 10 years in storage, spent fuel is still extremely dangerous.[Ref. 4] While the radioactivity in the "reference" PWR fuel assembly has declined from more than one million curies to about 180,000 curies, the remaining strontium-90 alone would be sufficient to contaminate Lake Mead (23 trillion gallons) beyond permissible drinking water standards. A person standing one yard away from an unshielded, 10-year-old fuel assembly would receive a lethal dose of radiation(500 rem) in less than three minutes. A thirty-second exposure(100 rem) at the same distance would significantly increase the risk of cancer or genetic damage.[Ref. 2]

Table 2
Radiation Characteristics of a Spent Fuel Assembly (33,000 MWd/MTU burnup)

Age (Years)	Activity (curies/assembly)	Surface Dose Rate (rem/hr)
1	2,500,000	234,000
5	600,000	46,800
10	400,000	23,400
50	100,000	8,640

Source: Reference 4

One measure of nuclear waste transportation risk is the potential exposure to members of the public from a truck shipment caught up in a traffic gridlock incident. There is no damage to the cask, but since NRC regulations allow emissions of 10 mrem/hour at 2 meters from the cask surface, passengers trapped in elevated vehicles (such as vans or buses) next to the cask could, according to DOE, receive exposures equivalent to several medical X-rays.[See Figure 4]

Figure 4

Exposure to Members of the Public in "Gridlock" Incident

DOE Assumptions:

- Group located 1 meter from vertical plane of trailer
- 4 - 8 people in vehicles closest to trailer
- Gridlock lasts 2 - 4 hours
- No remedial action to move group members
- Exposure rate to group: 5 - 10 mrem/hr

DOE Conclusions:

- Exposure to group member: 10 - 40 mrem

Source: Reference 5

A second measure of nuclear waste transportation risk is the potential consequence of a severe accident involving a very small release of cask contents. A DOE study prepared in support of the 1986 Environmental Assessment for the Yucca Mountain repository site evaluated the consequences of such an accident in a rural area and concluded that cleanup costs could exceed half a billion dollars. The results are summarized in Figure 5.

Figure 5

Consequences of a Rural Transportation Accident Resulting in Release

- Scenario: Rail Cask (14 PWRs), High-Speed Impact, Long-Duration Fire, Fuel Oxidation
- Release : 1380 curies of Co-60, Cs-134, Cs-137
- Area Contaminated: 42 Square Miles
- Clean-up Time: 460 Days
- Clean-up Cost: $620 Million

Source: Reference 6

The probability of an accident severe enough to cause even a small release of radioactivity is extremely low. The DOE study previously cited estimated the probability of the very severe rail accident at no more than two accidents per million shipments. [Ref. 6] Spent fuel transportation accidents and incidents have occurred, however, and the number will likely increase if past trends continue.

Between 1957 and 1964, there were 11 transportation accidents and incidents involving spent fuel shipments by the U.S. Atomic Energy Commission and its contractors. Several of these incidents resulted in radioactive releases requiring cleanup, including coolant leakage from a rail cask in 1960 and from a truck cask in 1962. There is no comparable data for the period 1964 to 1970, when utility shipments to reprocessing plants began.[Ref. 7] Between 1971 and 1990, there were six accidents and 47 incidents involving spent fuel casks. Three accidents (two truck, one rail) involved casks loaded with spent fuel. No radioactivity was released in these accidents. Most of the reported incidents involved excess radioactive contamination on cask surfaces, a result of the so-called "weeping" phenomenon on casks loaded and unloaded in wet storage pools. [Ref. 8]

Based on the 1971-1990 data, DOE calculated accident and incident rates for commercial spent fuel shipments to a repository. For truck shipments, DOE calculated 0.7 accidents and 10.5 incidents per million shipment miles. For rail shipments, DOE calculated 9.7 accidents and 19.4 incidents per million shipment miles. DOE compared these accident rates to the accident rates for large commercial trucks and freight trains in general service and concluded that the general truck and rail accident rates should be used for repository transportation risk and impact studies. DOE recommended using a truck accident rate of 0.7-3.0 accidents per million shipment miles and a rail accident rate of 11.9 accidents per million shipment miles. [Ref. 8]

The number of accidents and incidents likely to occur during spent fuel shipments to a repository can be obtained by multiplying these rates by the expected cumulative shipment miles over the life of the repository for two scenarios studied by Planning Information Corporation (PIC). [Ref. 9] If two-thirds of the shipments to a repository are made by rail, about 175 to 355 accidents and 425 to 925 reportable regulatory incidents would be expected over 30-40 years. If nine-tenths of the shipments are made by rail, about 185 to 250 accidents and 355 to 550 reportable regulatory incidents would be expected over 30-40 years.

The State of Nevada has identified a number of unresolved nuclear waste transportation safety issues.[Ref. 2] Two are of particular importance to terrorism risk assessment. First, the Department of Energy has made no commitment to full-scale testing of the new, high-capacity truck and rail shipping casks that will likely be used for shipments to a federal facility. Second, the Department of Energy has made no commitment to use dedicated trains, leaving open the possibility that spent fuel casks will be shipped in mixed freight trains.

An additional consideration in terrorism risk assessment is the public's perception of nuclear waste transportation risks. An extensive body of public opinion survey literature has documented that the public believes spent fuel transportation is very hazardous.[Ref.10] In Nevada, a majority of survey respondents believe that accidents are likely to occur and that the shipments cannot be made safe from terrorist attack.[Ref.11] The well-documented public dread of nuclear waste transportation could be a significant consideration in the selection of a nuclear waste shipment as a target for terrorist attack.

OUTLOOK FOR SHIPMENTS TO NEVADA

Under contract with the Nevada Agency for Nuclear Projects, Planning Information Corporation of Denver recently prepared a report on the outlook for nuclear waste shipments to Nevada for two scenarios: a repository at Yucca Mountain opening in the year 2010, the current plan; and a storage facility at NTS opening in 1999, as proposed in S. 1936. [Ref.9] Past NWPO analyses have focused on shipments to a repository. The new PIC report assumes that, for the repository- only scenario, shipments would begin in 2010; they would be primarily rail shipments; and truck shipments would use new, high-capacity casks. This scenario assumes a rail line to Yucca Mountain, no intermodal facility, and a total of 18,400 shipments over 30 years.[See Table 3]

Table 3

Outlook for Shipments to a Repository at Yucca Mountain (Current Plan)

- Shipments Begin: 2010
- SNF Modal Mix: 12% Truck, 88% Rail
- Casks: New Designs, High-Capacity
- Rail Access to Repository: Yes
- Intermodal Transfer Facility: No

Total Cask Shipments

• Legal-Weight Truck:	6,200
• Rail:	12,200
Combined Total:	**18,400**

Source: Reference 9

Under the legislation proposed in 1996, shipments to an interim storage facility (ISF) would have begun in late 1999. Legislation currently pending in Congress, H.R. 1270 and S.104, would begin shipments in 2002 and late 2002 or early 2003, respectively. Except for the shipment start date, the essential transportation details assumed for S.1936 in the

PIC report are the same as for H.R.1270 and S.104, and the PIC analysis of shipment numbers, modes, and routes applies equally to S.104 and H.R.1270.

S.104 and H.R.1270 would be expected to shift the modal mix heavily to truck. For the first five years or so, many truck shipments could be made using lower capacity, current generation casks such as the NAC LWT. The bills do not provide for construction of rail access, although rail access might be constructed at a later date. An intermodal transfer facility would be constructed at Caliente, Nevada, where large dual-purpose casks would be delivered by rail, then transported by heavy haul trucks on hundred and fifty foot long trailers to NTS. The total number of shipments to and within Nevada could increase dramatically. Depending on the capacity of the legal weight truck casks, there could be 56,600 to 104,500 total shipments. The lower number would occur if market conditions are favorable for the rapid deployment of a large fleet of GA4/9 casks or their equivalent. [See Table 4]

The PIC report also identified the most likely cross-country routes to Nevada for two scenarios. Assuming that Nevada does not designate alternative routes and that DOE contract motor carriers follow the quickest routes consistent with federal regulations, the primary east-west highway corridors would be I-80, I-70, and I-15. The base case primary rail corridor would be the Union Pacific mainlines out of Kansas City and Chicago, merging in Gibbon, Nebraska, and continuing west through Cheyenne and Salt Lake City. These routes are shown in Figure 6.

Table 4

Outlook for Shipments to an Interim Storage Facility and Repository (Proposed)

- Shipments Begin: 1999
- SNF Modal Mix: 35% Truck, 65% Rail
- Casks: Current Designs, Current Capacity
- Rail Access to Repository: No
- Intermodal Transfer Facility: At Caliente
- Total Cask Shipments

Total Cask Shipments	Current Casks	(New Casks)
Legal-Weight Truck:	79,300	(31,400)
Rail:	12,600	(12,600)
Heavy Haul Truck:	12,600	(12,600)
Combined Total:	**104,500**	**(56 ,600)**

Source: Reference 9

PIC also identified alternative southern highway routes that might be used if DOE and its contractors seek to minimize winter weather disruptions for trucks using I-80 and I-70 through the Rocky Mountains and to avoid a legal fight with the State of Colorado over shipment restrictions through the Eisenhower and Glenwood Tunnels. PIC also identified an alternative southern rail route that considered recent rail industry mergers and acquisitions and considered the possibility that the Union Pacific might seek to avoid nuclear waste shipments along its high-traffic-density mainlines through Nebraska. Under these circumstances, PIC concluded that I-40 could be the primary east-west highway corridor and that the Santa Fe-Burlington Northern line from Kansas City to San Bernadino could be the primary east-west rail corridor. These routes are shown in Figure 7.

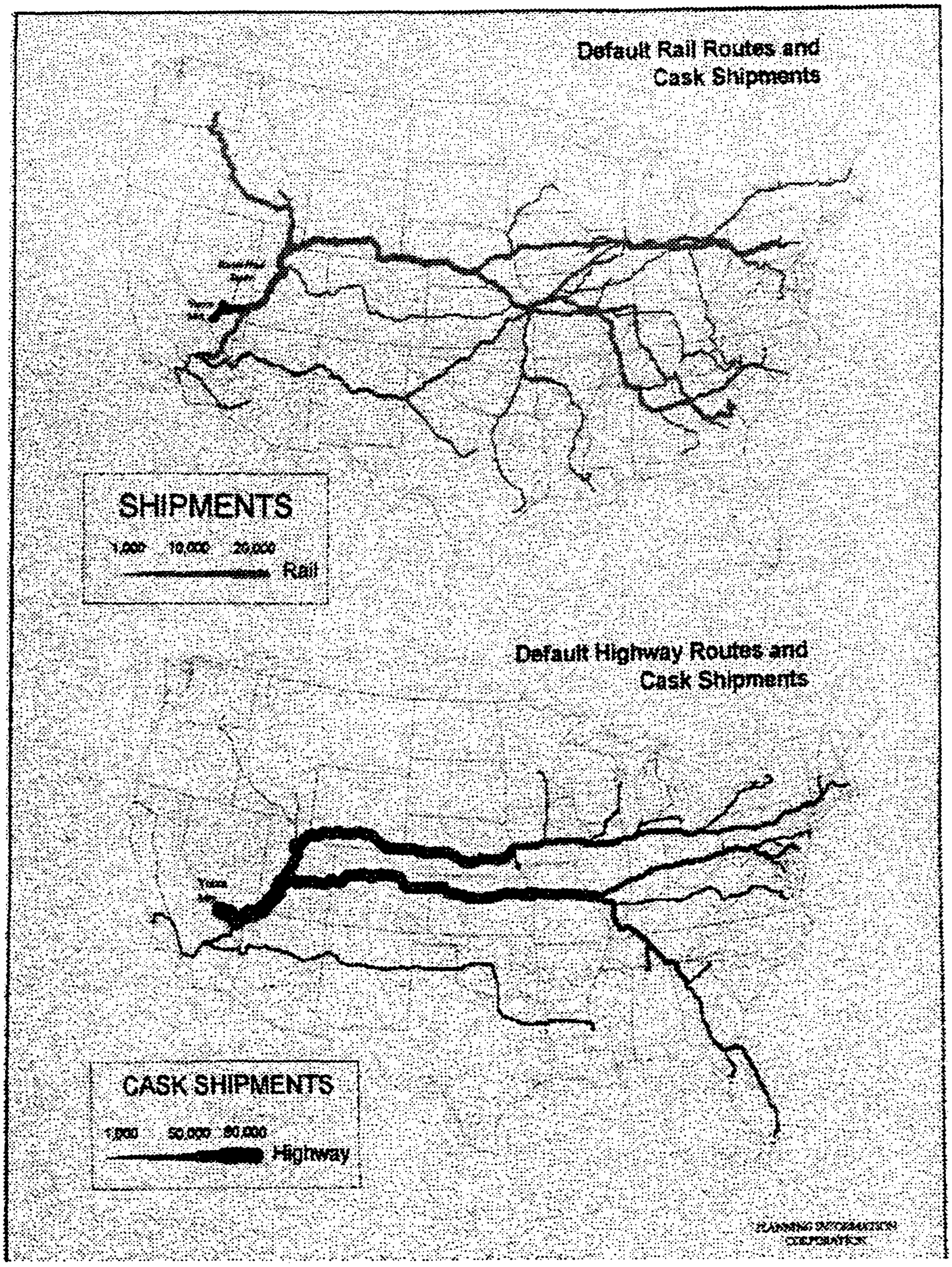


Figure 6. Base Case Nuclear Waste Transportation Routes to Nevada

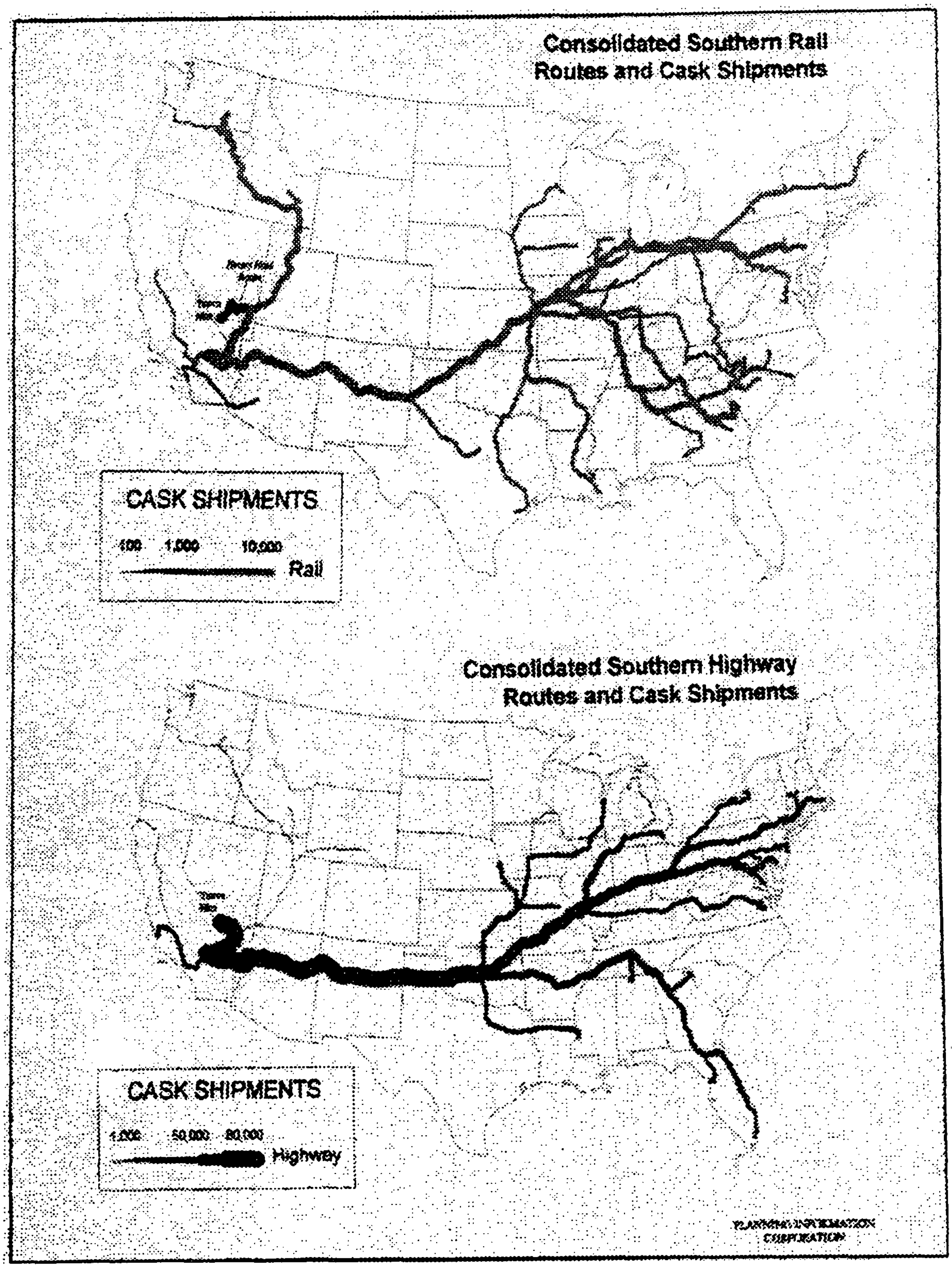


Figure 7. Alternative Nuclear Waste Transportation Routes to Nevada

PIC also identified the most likely nuclear waste routes within Nevada for the base case and southern routing scenarios. Under the base case, about 85 percent of rail shipments enter Nevada on the Union Pacific line from Utah, with the remainder entering from California and traversing downtown Las Vegas. [See Figure 8] Under the southern routing scenario, about two-thirds of the rail shipments enter Nevada from California on the Union Pacific line through Las Vegas. [See Figure 9] If no rail spur is constructed, rail casks would be moved by heavy haul trucks (HHT) from Caliente to NTS by one of several possible highway routes. Under the base case, the majority of legal-weight truck shipments would travel I-15 from Utah and Arizona to the Las Vegas intersection with US 95, known locally as the Spaghetti Bowl. Under the southern routing scenario, the majority of truck shipments would enter Nevada from California on I-15 and proceed to the Spaghetti Bowl.

In the absence of a State of Nevada designation of alternative routes, the vast majority of truck shipments from reactors in the eastern U.S. would traverse the Las Vegas Valley en route to Yucca Mountain or NTS. The Nevada Department of Transportation (NDOT) has identified a number of possible alternative highway routes that would avoid the Spaghetti Bowl. Some of the potential alternatives (Craig Road and State Route 160), would still affect the Las Vegas Valley. Nevada designation of the so-called NDOT B Route would shift the point of entry to West Wendover off of I-80 from Utah and route the majority of shipments through northeastern and central Nevada on US 93A, US 93, US 6, and US 95. Many observers believe that political pressure from Clark County will result in the eventual designation of the NDOT B Route. To date, NDOT has not formally designated any alternative routes for spent fuel shipment, and it cannot be assumed that NDOT will designate any alternative routes because of legal liability issues and because the risk factors for some alternatives are changing (for example, rapid population growth near West Wendover). Until NDOT formally designates different routes, the base case routing assumption is that shipments will come through the Las Vegas Valley on I-15 and US 95.

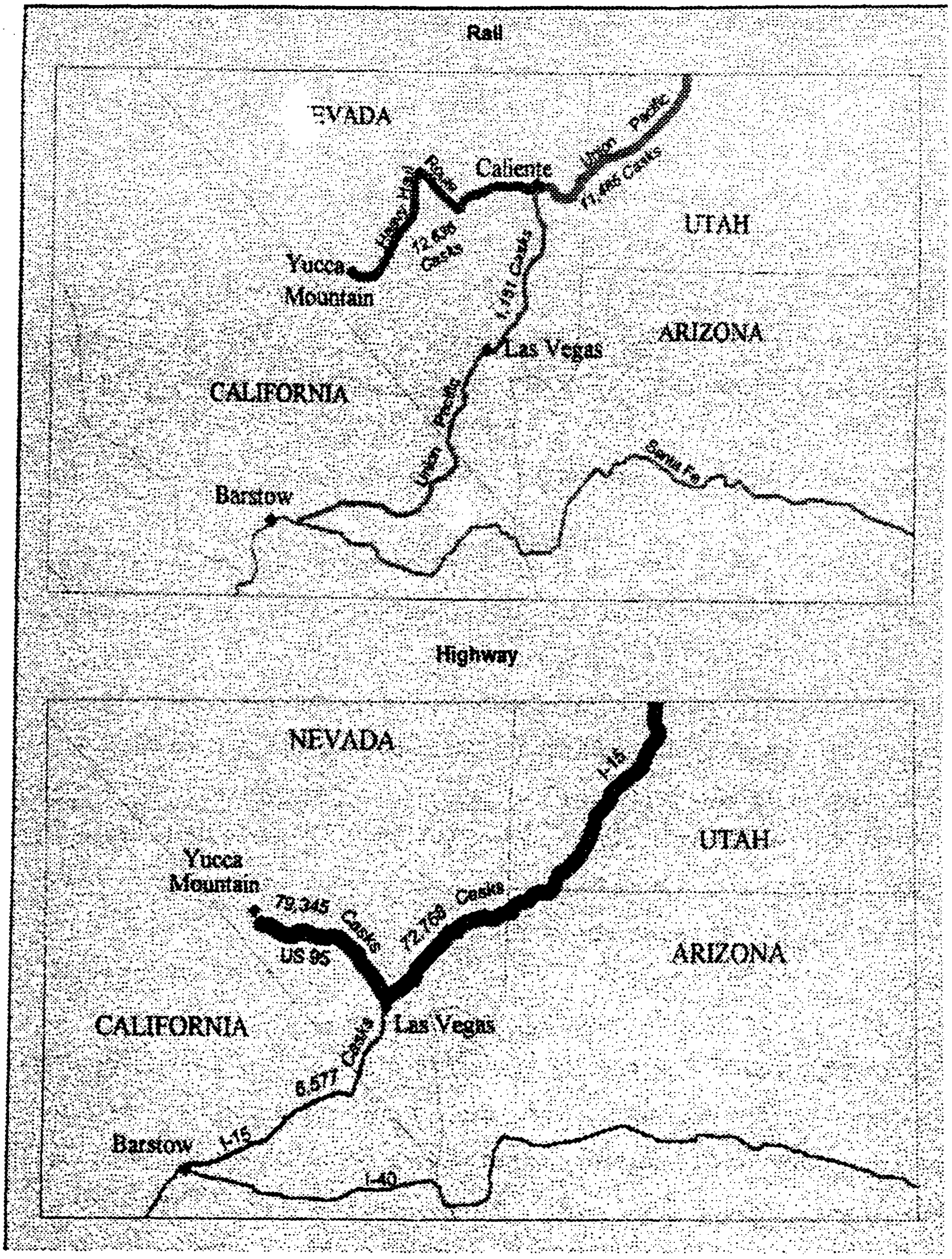


Figure 8. Base Case Nuclear Waste Transportation Routes in Nevada

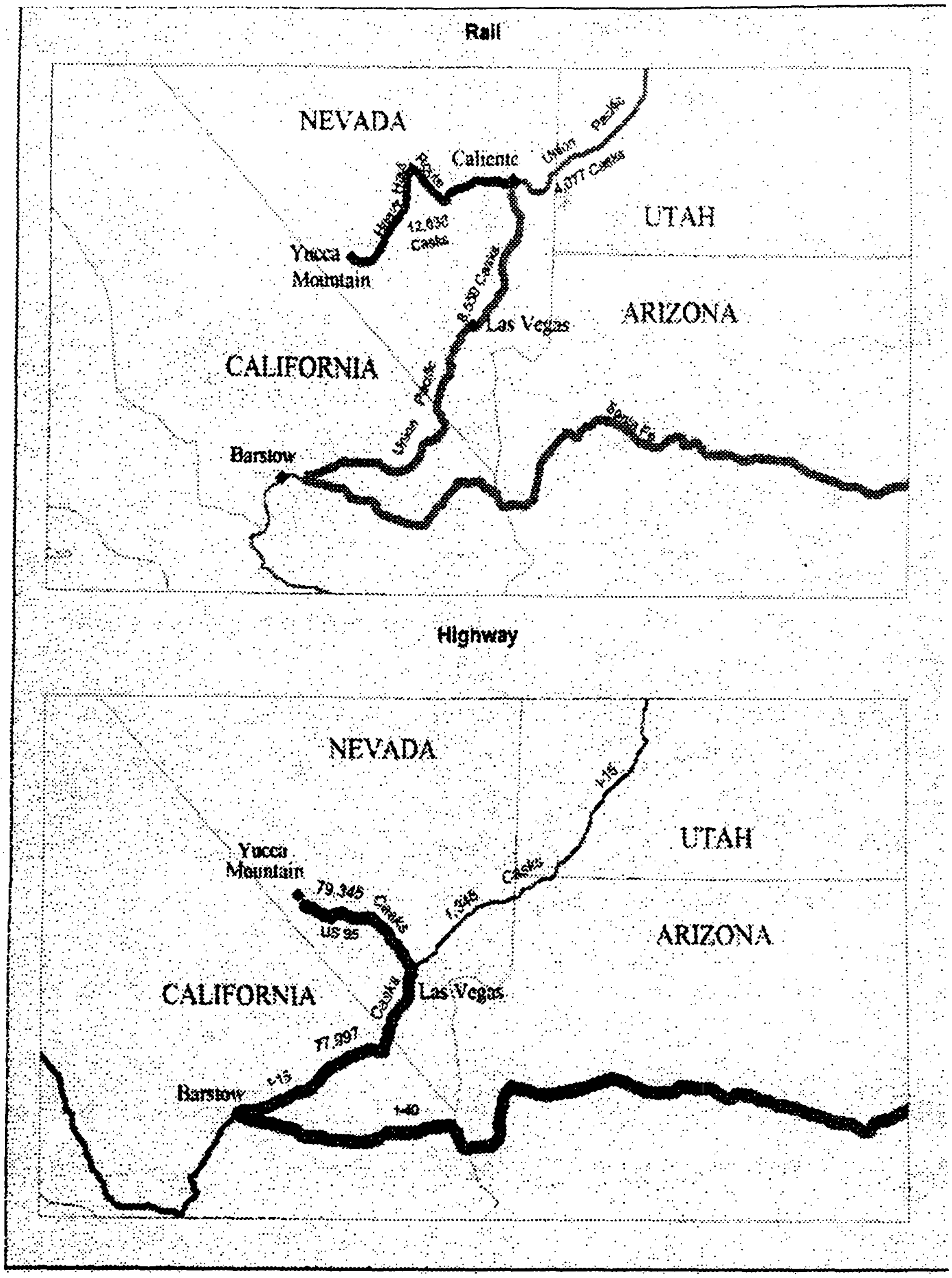


Figure 9. Alternative Nuclear Waste Transportation Routes in Nevada

SHIPMENT CHARACTERISTICS RELEVANT TO TERRORISM RISK ASSESSMENT

Based on the outlook for shipments to Nevada developed by PIC, it is possible to identify certain characteristics of these shipments that are particularly relevant for terrorism risk assessment. These characteristics are summarized in Figure 10.

Figure 10

Shipment Characteristics Relevant to Terrorism Risk Assessment

- Multiple Modes and Routes
- Long Distance Shipments (>2,000 miles)
- Daily Shipments (3 - 9 per day)
- Routes through highly populated areas
- Routes that place shipments in tactically disadvantageous positions
- Routes with marginal safety design features
- Routes with limited rest and refueling locations
- Routes with low likelihood of swift local law enforcement agency response

Multiple Modes and Routes. Under any of the scenarios identified, spent fuel and high-level nuclear waste will be traveling to Nevada, and within Nevada, by multiple transport modes and routes. Any potential adversary will therefore have a variety of transportation targets and attack environments from which to choose. Those responsible for protecting shipments will have to defend a number of different routes (some exceeding 300 miles in length) and different locations in different parts of the State.

Long Distance Shipments. The overwhelming majority of rail and legal weight truck shipments to Nevada will be long distance shipments of 2,000 miles or more. This is particularly important for truck shipments. On average, truck drivers and their equipment will have been on the road for 40 to 60 hours by the time they get to Nevada. Driver fatigue and equipment performance will have to be considered in any meaningful assessment of shipment vulnerability. Likewise, fatigue could be a concern for shipments and shipment escorts within Nevada along the NDOT B Route for legal weight truck shipments, along all of the heavy haul truck routes from Caliente to NTS, and for rail shipments within Nevada if an access spur is constructed along the Carlin or Caliente routes.

Daily Shipments. Spent nuclear fuel and high-level waste will be shipped to and within Nevada on a daily basis for 30 years or more, a period of almost 11,000 days. Depending upon the scenario, Nevada can expect between two and nine shipments from out-of-state every day for 30 years. In addition, if Congress mandates the operation of an intermodal transfer facility at Caliente, Nevada can expect an average of one or two heavy haul truck shipments every day for 30 years. Compared to the relatively small numbers of past and current spent nuclear fuel shipments, the frequency and regularity of shipments to a storage facility or a repository will create enormous opportunities for any potential adversaries. Those shipments will have to be protected from terrorism and sabotage every day for at least 11,000 days.

The NRC has identified five types of route characteristics that receive special consideration when NRC staff review routes for approval pursuant to 10 CFR 73: (1) routes through highly populated areas; (2) routes that would place the shipment or the escort vehicle in a significantly tactically disadvantageous position (for example, tunnels that would prevent the escort vehicle from maintaining continuous surveillance of the shipment vehicle); (3) routes with marginal safety design features (for example, two-lane routes, absence of guard rails, etc.; (4) routes with limited rest and refueling locations; and (5) routes where responses by local law enforcement agencies, when requested, would not be swift or timely.[Ref. 12] The Nevada routes likely to be most heavily used for shipments to Yucca Mountain or NTS exhibit many of the avoidance factors identified in the NRC safeguards regulations and regulatory guidance document.

Routes through highly populated areas. Under both the base case and the southern alternative routing case, the primary highway and rail routes traverse downtown Las Vegas. The NRC Guidance Document specifically identifies Las Vegas (and Reno) as a highly populated area for safeguards route evaluation purposes. The ten-mile corridors along the I-15 and US 95 routes through Las Vegas contain almost one million people. The estimated nonresident population of the same corridors is over 300,000 and includes all the major hotels and casinos of the Las Vegas Strip. Indeed, the estimated nonresident population within the one-mile corridor along I-15 from California is over 110,000. [Ref. 13,14]

Routes that place shipment vehicles in significantly tactically disadvantageous positions. NRC has specifically identified the presence of tunnels as a disadvantageous route characteristic. Tunnels are a prominent feature of the Union Pacific mainline through southeastern Nevada, the most likely route for shipments using a newly constructed repository rail access spur or an intermodal transfer facility at Caliente. There are eight tunnels on the Union Pacific route between the Utah-Nevada border and Caliente and seven tunnels between Las Vegas and Caliente on the route through Meadow Valley Wash and Rainbow Canyon. Rail shipments along the Union Pacific mainline in northern Nevada, which could be a primary route if a new repository access spur originates between Carlin and Battle Mountain, would travel through as many as five tunnels after entering Nevada at West Wendover. [Ref. 15]

The State of Nevada believes that the definition of route features that result in a significantly tactically disadvantageous position should explicitly include the steep grades and sharp curves typically associated with high mountain passes on western highways. There are numerous examples along the NDOT B Route [White Horse Pass, Currant Summit, Black Rock Summit, Sandy Summit, Warm Springs Pass, Tonopah Summit, Goldfield Summit, Stonewall Pass] and along the proposed HHT route from Caliente to NTS [Oak Springs Summit, Pahroc Summit, Hancock Summit, Coyote Summit, Queen City Summit]. These grades, often as steep as 5 to 7 percent, require trucks ascending passes to slow down to speeds of 35 miles per hour or less in good weather. Even slower speeds are required during winter storms. Cautious driving is also required when tractor trailers descend from these summits. Both the steep grades and the sharp curves associated with these passes will make continuous visual contact between the shipment vehicle and any escort vehicles difficult. More importantly, the slow speed of trucks climbing these grades, combined with grade lengths of four to six miles or more, will make shipments more vulnerable to attack while moving. The terrain along these route segments frequently includes dropoffs into deep canyons or river valleys that would make response to an attack or recovery of a cask, damaged or not, quite difficult. The rough terrain, coupled with the remoteness and isolation of many highway segments, would provide potential attackers with hiding places and escape routes.

The State of Nevada also believes that the steep grades and sharp curves along certain rail routes may place nuclear waste shipments at a significantly tactically disadvantageous position. One such route segment of particular concern is located along the Union Pacific mainline between Crestline and Caliente, where the track elevation drops from 6000 feet to 4250 feet over a distance of about 37 miles. [Ref. 15] Under the current base case routing scenario for shipments to an intermodal transfer facility at Caliente, this segment could be the most heavily traveled nuclear waste rail route in the United States.

Routes with marginal safety design features, limited rest and refueling locations, and limited law enforcement response capabilities. For truck shipments, the NRC route selection criteria clearly prefer interstate highways because of their advanced safety design features, specifically, divided highways, guard rails, and limited access. In Nevada, the present preferred routes, I-15 to Las Vegas, and US 95 from Las Vegas to Mercury, meet the NRC's standards for "good transportation safety design features." The most likely state alternative routes identified to date, and the most likely HHT routes between Caliente and NTS, do not meet the NRC route selection criteria. To the contrary, the likely alternative routes are almost exclusively two-lane highways with narrow road shoulders, limited guard rails, and virtually unlimited access (especially if the potential adversaries are equipped with off-road vehicles). Moreover, the only routes in Nevada likely to meet the NRC standards for rest and refueling locations and swift law enforcement response capabilities are the routes through the state's most heavily populated areas. Indeed, the potential alternative routes, especially the NDOT B Route, are characterized by long segments (up to 60 miles in length) where there are no safe parking areas, no refueling facilities, and very limited local law enforcement response capabilities.

PREVIOUS ASSESSMENTS OF TERRORIST ATTACK CONSEQUENCES

In the early 1980s, NRC and DOE sponsored research on the consequences of terrorist attacks on spent nuclear fuel shipping casks. These DOE and NRC research studies were designed to address concerns raised by earlier government reports, particularly a 1977 draft assessment by Sandia National Laboratories, Transport of Radionuclides in Urban Environs, which concluded that sabotage of a truck cask could result in several tens of early fatalities and hundreds of latent cancer fatalities and that sabotage of a rail cask could result in hundreds of early fatalities and thousands of latent cancer fatalities. [Ref. 16] A revised and expanded version published in 1980 as Transportation of Radionuclides in Urban Environs: Draft Environmental Assessment [SAND79-0369/NUREG/CR-0743] reduced the estimated consequences, but still concluded that a successful attack using high-energy explosives in a highly populated area could cause hundreds to thousands of casualties. Radiological health effects were expected to be primarily early morbidities (illnesses appearing within weeks after exposure) and latent cancer fatalities. Early radiological fatalities were not expected because "those close enough to receive lethal radiation doses would be killed by the explosion." The study considered releases of 10% to 25% of the noble gases (primarily Kr-85) and 0.07% to 0.2% of the solids as respirable material from a truck cask containing three 150-day cooled PWR fuel assemblies and a rail cask containing 10 PWR assemblies. For an attack releasing 1,000 to 11,000 curies of the cask contents in respirable form in an industrial area, the economic costs of emergency response, recovery and cleanup, and denial of use of contaminated property were estimated to range from $500 million to $3.0 billion (in 1979 dollars). The cost estimate did not include the "indirect sociopolitical, economic or litigation costs of the loss (however temporary) of the business, finance and government facets of an urban area ... ." [Ref. 17]

Acknowledging the potential threat, NRC issued interim physical protection requirements for spent fuel shipments in July, 1979. NRC subsequently issued a proposed rule, took public comments, and promulgated an amended rule as 10 CFR 73.37(a) through (e), effective July

3, 1980. This rule established the current system of physical protection requirements including advance notification of the NRC, procedures for coping with safeguards threats and emergencies, designation of heavily populated areas, instructions to escorts (including use of deadly force by armed escorts in heavily populated areas), establishment of a communications center, maintenance of shipment logs, arrangements with local law enforcement agencies, advance route approval by NRC, avoidance of intermediate stops, procedures for stops, escort training requirements, and periodic contacts with the communications center. Additional requirements specific to road, rail, and sea shipments were established. NRC issued an interim guidance document, Physical Protection of Shipments of Irradiated Reactor Fuel [NUREG-0561, Rev. 1], in June, 1980, to explain the new requirements to potential shippers and carriers. [Ref. 12]

Meanwhile, NRC and DOE sponsored additional research on the consequences of terrorist attacks and/or sabotage involving high-energy explosives. NRC stated that additional research was needed because the original draft report that "prompted issuance of the protection requirements, contained estimates that were unavoidably subject to large uncertainties due to a lack of technical data," and even with the lower consequences estimated by the subsequent report, "a significant degree of uncertainty still remained that could be resolved only by further study and experiments." The experimental program was premised on two critical assumptions: "(1) that consequences of an act of sabotage would be a direct function of the quantity of spent fuel that would be released in respirable form [particles having a diameter of less than four microns]; and (2) that the only credible means of malevolent generation of respirable particles would be through the use of a large quantity (tens to hundreds of pounds) of high explosives skillfully applied." [Ref. 16] Both of these assumptions would later be challenged.

NRC sponsored a series of scale-model tests and laboratory analyses conducted by Battelle Columbus Laboratories to assess the response of shipping containers and irradiated spent fuel to attacks with explosives. The results were published in October, 1982. [Ref. 18] DOE sponsored a separate but coordinated program of studies, including one full-scale and several scale-model tests at Sandia National Laboratories. Those results were published in October, 1983.[Ref. 19] Many reviewers considered the full-scale test conducted at Sandia the most important aspect of the entire research program, and the test assumptions, instrumentation, data collection and analysis, and interpretation of results later became the subject of considerable controversy. Inside a pressurized containment vessel, a General Electric IF-200 truck cask containing an unirradiated fuel assembly was attacked with a military shaped charge, the U.S. Army M3A1. The results, illustrated in Figures 11 and 12, demonstrated that casks could indeed be breached by military explosives and that a considerable fraction of spent fuel could be released by such an attack, although only a small fraction of the release consisted of respirable particles.

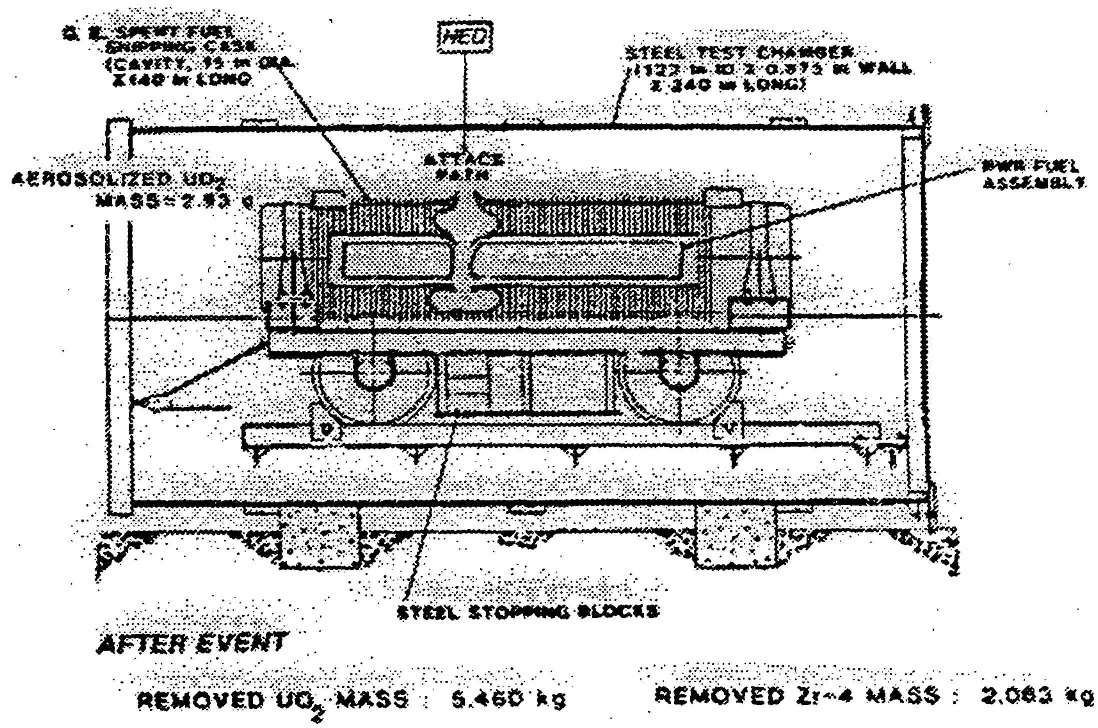


Figure 11. Sandia Full-Scale Test: Schematic of Test Configuration Immediately After Detonation

Figure 12

Sandia Full-Scale Test: Scenario and Summary of Results

- Scenario: Terrorists Attack Truck Cask Containing 1 PWR Assembly with HED (M3A1)
- Hole Diameter: 152.5 mm (6.0 inches)
- Fuel Rods Damaged: 111 of 223 (50%)
- Fuel Mass Fractured: 20.82 kg (10%)
- Fuel Mass Released: 2.55 kg (5.6 pounds) (1%)
- Released as Aerosol: 2.94 g (1/10 ounce)

Source: Reference 19

In summarizing the findings of these experiments, NRC maintained its focus on the release of respirable particles. Irradiation and contamination as a result of the loss of shielding and the dispersal of larger particles of spent fuel were ignored, perhaps because these events had been downplayed in Sandia's revised urban transportation study. [Ref. 17] For example, in a pamphlet designed to educate the general public about the safety of spent fuel shipping casks, NRC summarized the findings thusly: "A shipping cask has been subjected to attack by explosives to evaluate cask and spent fuel response to a device 30 times larger in explosive weight than a typical anti-tank weapon. This device would carve an approximately 3-inch diameter hole through the cask wall and the contained spent fuel and is estimated to cause the release of 2/100,000 of the total fuel weight (~10 grams of fuel) in an inhalable form." [Ref. 20]

Based on these findings, NRC dramatically reduced its estimate of the consequences of a successful terrorist attack. NRC-sponsored researchers "found that the average radiological consequence of a release in a heavily populated urban area such as New York City would be no early fatalities and less than one (0.4) latent cancer fatality. ... For the most densely populated area studied (up to 200,000 persons per square mile), at evening rush hour on a business day, and in the most unfavorable location for a release, the calculated radiological consequence (peak consequence) ... is no early fatalities and less than three (2.9) latent cancer fatalities. ... the releases and health consequences for a three-assembly cask are calculated to be, at worst, double those for a single-assembly cask. The presence of additional assemblies in a cask would increase the likely release, but only in proportion to the number of assemblies that lie in the roughly straight line path of the jet. For more than three PWR assemblies (a fully loaded rail cask could contain 10 PWR assemblies), the upper bound release would likely increase roughly in proportion to the square root of the total number of assemblies contained in a cask." NRC added that DOE-sponsored studies confirmed that the "peak consequence" of a 17 gram release "in a heavily populated area such as New York City" would be "no early fatalities and about 7 latent cancer fatalities" for a single-assembly cask and double that amount (14 latent cancer fatalities) for a three-assembly truck cask. [Ref. 16]

Based on these new research findings, the NRC concluded that the consequences of a terrorist attack on most shipments of irradiated reactor fuel no longer justified the strict physical protection requirements adopted in 1980. While retaining the original requirements for shipments of spent fuel cooled less than 150 days, the NRC, in June, 1984, proposed eliminating certain requirements for other shipments: armed guards for shipments through highly populated areas, advance review and approval of shipping routes, advance notice to local law enforcement agencies along routes, and periodic communications between escorts and a communications center while shipments were under way.[Ref. 16] Since fuel cooled less than 150 days was unlikely to be shipped under normal circumstances, the proposed rule for all intents and purposes eliminated major physical protection requirements for all anticipated spent fuel shipments.

The NRC published its proposed rule and a summary of the research findings in the Federal Register on June 8, 1984. The notice allowed 90 days for written comments, but the NRC apparently accepted comments as late as January, 1985. At least 32 parties submitted more than 100 pages of comments in response to the notice. Many commenters not only opposed the proposed rule, but also submitted detailed criticisms of the research findings upon which the proposed rule was premised. The NRC never publicly responded to these criticisms. No final rule was issued, although the proposed rule was never formally withdrawn. On January 20, 1987, the NRC Executive Director of Operations "terminated activity on this rulemaking." [Ref. 21]

Because of the manner in which the rulemaking was terminated, the DOE- and NRC-sponsored research findings and the NRC's interpretation of those findings were never fully debated in a public forum. Figure 13 summarizes the major criticisms raised by commenters in response to the Federal Register notice and afterwards. A draft study prepared for the Nevada Agency for Nuclear Projects concluded that the NRC had seriously underestimated the potential damage to the cask and spent fuel and the potential health effects of the resulting release of radioactive materials. [Ref. 22]

Figure 13

Primary Criticisms of the NRC's 1984 Terrorism Consequence Assessment and Proposed Rule

- NRC underestimated potential damage to cask and spent fuel
- NRC underestimated potential health effects of attack resulting in release
- NRC did not evaluate standard economic impacts of attack resulting in release
- NRC did not evaluate special social and economic impacts of attack resulting in release
- NRC terminated rulemaking without explanation or response to comments
- NRC and DOE continue to use findings as basis of terrorism risk assessment

A detailed discussion of these criticisms is beyond of the scope of this article. However, three issues deserve special attention here. First, NRC failed to evaluate the consequences of the full amount of spent fuel released to the environment by a terrorist attack using explosives. Neither logic nor evidence support the NRC's contention that the "consequences of an act of sabotage would be a direct function of the quantity of spent fuel that would be released in respirable form [particles having a diameter of less than four microns]." [Ref. 16] The Sandia full-scale test may or may not have represented a worst case attack, but it did demonstrate that a successful attack could disperse 1% of the cask contents, more than five pounds of spent fuel fragments, from a cask containing one irradiated PWR assembly. The NRC's approach to such an event would be to evaluate only the health effects of the fraction of an ounce of material released as a respirable aerosol and to ignore the human health, environmental, economic, and social consequences of the total release, which would likely involve about 2,000 curies, and the gamma and neutron radiation emitted from the damaged cask. Even if the blast damage and contamination zone were confined to an area within 100 meters, an area of about 8 acres, the consequences of such an attack in a highly populated urban area certainly deserve a more thorough assessment than that conducted by the NRC and its contractors. [Ref. 23]

Second, the NRC failed to consider the potentially severe social impacts of a successful terrorist attack. This omission is difficult to understand, since NRC was a major sponsor of social impact research in the late 1970s, and an NRC contractor report published in 1980 warned that a successful terrorist attack could "produce large psychological consequences. Close friends or relatives of those who were killed or injured would experience intense grief, possibly prolonged by the belief that the deaths were preventable. Those individuals who were contaminated could experience anxiety about long-term health effects, which could cause other mental health problems such as loss of sleep and loss of appetite. Although these impacts would be limited to those directly affected by the event, media coverage would be widespread and belief changes would likely occur nationwide." [Ref. 24]

The same report reviewed the psychological, social, legal, and organizational impacts of "malevolent acts" against radioactive materials transportation, and concluded: "...a successful event in any urban area, such as terrorists threatening and carrying out the sabotage of a shipment of high-level radioactive material with subsequent dispersal, could cause widespread social impacts. Such events would produce many of the same impacts as a serious vehicular accident, except that causal attribution would be different. In addition, individuals in the community would undergo more fear and anxiety, because of the terrorist component, than would be the case for a vehicular accident. This could lead to social disruption. News coverage of such an event would be extensive and widespread, serving as motivation for existing organized groups locally and nationally to step up their opposition to nuclear power generally and to transportation specifically. Ambiguities about responsibility at the local, state, and federal level for the response to such an event would become apparent, and, after the event, would likely become more clearly delineated through new statutory or regulatory requirements." [Ref. 24]

Third, DOE uncritically adopted NRC's terrorism risk findings and proposed reduction in safeguards regulations as part of its 1986 environment assessment (EA) for the Yucca Mountain repository candidate site. After reviewing the NRC and DOE-sponsored studies and NRC's 1984 proposed rules, DOE's Yucca Mountain EA concluded: "Though transportation packages have not been specifically designed to mitigate the consequences of a sabotage event, they have been shown experimentally to limit to low levels the potential adverse health consequences to the public. Predictions based on releases experimentally determined in both DOE and NRC studies indicate no immediate radiation-induced deaths and a small number of latent cancer fatalities would be expected even in a very densely populated area (Sandoval et al., 1983). To create the level of hazard encountered in the experiments, such sabotage attempts would have to be performed by trained experts, and precise placement of the explosives in the most vulnerable positions would be necessary." DOE's EA added reassuringly: "In order to protect the health and safety of the public, the packaging of shipments made to a repository will be as strong as those used in the experimental studies." [Ref. 25]

PREFERRED APPROACH TO ASSESSING THE RISKS OF TERRORISM AND SABOTAGE AGAINST REPOSITORY SHIPMENTS

In 1988, NWPO hired an independent contractor, Mountain West Research (MWR) of Phoenix, Arizona, to prepare a comprehensive high-level nuclear waste transportation needs assessment (TNA). MWR assembled an expert study team which identified and prioritized major issues to be addressed in the State of Nevada nuclear waste transportation impact assessment program. The TNA described and critiqued DOE's planned transportation system, developed a set of preferred management options that would maximize safety and minimize adverse impacts to Nevada, and recommended an interdisciplinary study plan for transportation impact assessment, risk communication, and risk management. [Ref. 26]

As part of the TNA, MWR developed a set of preferred management options for the physical protection of spent nuclear fuel and HLW shipments to a centralized geologic repository. From the beginning, the MWR study team emphasized the difficulty of applying probabilistic risk analysis: "Social risks, such as sabotage and terrorism, are difficult to quantify. Since these actions are directed towards deliberate destruction of containers or vehicles, however, a few attempts may be sufficient to release a large amount of radioactivity or, in the case of manipulation, to cause an accident. Hence, the small probability of occurrence is superseded by the near-certainty of the effect. That is why risk management has to deal with these risks in great detail; for just one incident may well cause tremendous damage. But even incidents causing only minor damage are likely to yield a long-lasting impact on social and political perceptions. This could not only weaken public confidence and trust in official decision makers and decision-making institutions, but also hurt economies in the host state and corridor states." [Ref. 26]

Figure 14 presents a list of options for terrorism and sabotage identified by the MWR study team.

Figure 14

Options for Terrorism and Sabotage Against Nuclear Waste Shipments

1. **Use of explosives**
   - air blasts
   - contact or breaching charges
   - shaped charges
   - platter charges

2. **Highjacking of transportation vehicles**
   - stealing a vehicle during a work break
   - gaining control over the vehicle in a remote area
   - taking a driver as hostage
   - stopping a vehicle and threatening to blow it up

3. **Manipulating the vehicle**
   - initiating malfunctions of safety related devices (breaks, steering wheel, tires)
   - placing obstacles on the road (like glass splinters)
   - loosening the links between vehicle and container

4. **Manipulating the vehicle's operator**
   - smuggling drugs into operator's diet
   - exerting physical power on the operator
   - blackmailing the operator
   - exerting psychological power on the operator (like threatening to kill family members)

5. **Theft**
   - initiating an accident for obtaining material
   - initiating a highjacking for obtaining material
   - theft of a vehicle during a night stop
   - exchange of vehicles during a night stop
   - armed robbery during loading or unloading

Source: Reference 26

In order to evaluate these terrorism and sabotage options, the TNA recommended a risk assessment/risk management process involving six steps: scenario assessment, vulnerability analysis, screening of management options, resilience analysis, decision analysis, and sensitivity analysis. The recommended process depended heavily upon credible scenario assessment, and the MWR study team emphasized the limited usefulness of probabilistic analysis for these purposes.

The MWR study team report also stated: "Traditional risk assessment methods rely on a sufficient data base to derive meaningful probabilities for each investigated incident. Furthermore, the occurrences of failures must follow a specific pattern including random variation. But sabotage and terrorist attacks meet neither of these criteria. Past data on human intrusion does not allow any numerical extrapolation to determine relative frequencies nor do we have a good model on the underlying distribution function of such incidents. Apparently, terrorist attacks are not randomly distributed, but depend on political or psychological circumstances. Unless we find an adequate model to explain and predict such circumstances, we are unable to determine probabilities for different types of incidents. Using expert judgment to elicit probabilities does not overcome this conceptual problem, because experts themselves lack the necessary knowledge to make such judgments." [Ref. 26]

The TNA recommended an alternative approach, summarized in Figure 15, for "the construction of scenarios and their rank ordering."

Figure 15

Recommended Approach to Terrorism Scenario Assessment

- **Interpretive methodology**: role playing by researchers or groups of experts, based on assumption that terrorists will design attacks on traditional concept of cost-effectiveness
- **Consider range of attack objectives and methods**: disruption of shipments, accident without release, accident or attack with explosives intended to cause release
- **Consider range of perpetrators**: political terrorists, antinuclear radicals, right-wing extremists, disgruntled employees

Source: Reference 26

The authors of this paper have reviewed and reconsidered the MWR study team's recommendations in light of developments over the past decade. We generally agree with the TNA's contentions regarding the limited value of probabilistic analysis and predictive modeling for terrorism risk assessment. The TNA did not specifically address the issues of terrorism event definition, data collection, and analysis. Ballard's report [Ref. 27] examines these matters and supports the conclusion that current data bases on nuclear terrorism and sabotage in the United States, such as the NRC's Safeguards Summary Event Listing(SSEL), are not adequate to support probabilistic analysis or predictive modeling. (One problem is the NRC SSEL's restrictive definition of radiological sabotage as a "deliberate act directed against a safeguarded activity which could endanger the public health and safety by exposure to radiation.") [Ref. 28] However, we believe that dedicated data collection and improved analysis could significantly enhance terrorism risk assessment and risk management activities. Prior to any attempt to construct reasonably accurate risk assessment studies, improved information resources are needed regarding terrorism and sabotage events generally, terrorist attacks on transportation infrastructure and nuclear facilities, and all events that appear to be specifically intended to disrupt spent nuclear fuel and/or high-level radioactive waste shipments in the United States and abroad.

A comprehensive assessment of the risk of terrorism and sabotage against repository shipments should, at a minimum, fully evaluate three types of actions: (1) actions to disrupt shipments without causing damage to the cask; (2) actions to induce severe accidents, possibly causing damage to the cask and release of contents; and (3) attacks on shipping casks that are clearly intended to cause a release of radioactive materials.

Actions to disrupt shipments without causing damage to the cask. Experience with such incidents primarily involves mass demonstrations, using tactics ranging from passive civil disobedience to violent confrontation, intended to stop specific shipments of spent nuclear fuel or high-level waste or as a means of making a larger political statement. We assume that incidents of this nature are not intended to cause a release of radioactive materials. Such incidents would clearly not meet the NRC's definition of radiological sabotage, but have the potential, by accident or design, to create a hazardous situation.

The most significant disruption event to date occurred in Germany in early March, 1997, when thousands of protesters attempted to stop a shipment of spent nuclear fuel to an interim storage facility. The shipment consisted of one train hauling six 100-ton CASTOR casks 400 miles from Walheim, near Stuttgart, to Dannenberg, a small city in northern Germany. There the casks were transferred to heavy haul trucks and transported about 11 miles to an above-ground storage facility near Gorleben. Human blockades along the rail route and a pipe bomb attack on the tracks delayed the shipment eight hours. In one instance, according to press reports, "two men cemented themselves to the tracks and had to be removed with jack hammers." More than 10,000 demonstrators attempted to disrupt the truck shipments from Dannenberg to Gorleben. Protester tactics included human blockades, farm tractors chained together, barricades of trees and cement, and tunneling under the roadway of the preferred route. A minority of the protesters engaged in violence, hurling stones and firebombs at the large police force present. It is not unreasonable to foresee an escalation of violence that could directly threaten cask shipments under these conditions. The protests did not prevent the shipment from reaching its destination. However, security for the shipments required "the largest police operation in Germany's postwar history, involving around 30,000 officers," with total security costs estimated at $40 million to $60 million. [Refs. 29,30,31,32,33]

There have been protests against nuclear waste shipments in the United States, mainly involving relatively small numbers of people engaged in peaceful picketing, but to date, there have been no attempts to disrupt shipments comparable to the March, 1997 protests in Germany. However, protest demonstrations in southern Nevada during April, 1997, may indicate significant potential for disruption of nuclear waste shipments to Yucca Mountain or to an interim storage facility at the Nevada Test Site(NTS). At the end of a week of demonstrations in Las Vegas and at the NTS entry gates, demonstrators protesting against nuclear waste storage and disposal and against weapons testing, stopped traffic for three hours on US 95, the major highway route to Yucca Mountain. Police arrested 24 protesters who closed the road 65 miles northwest of Las Vegas by chaining themselves to vehicles and steel drums filled with concrete. "Approximately 60 police officers and security guards had to be called to the scene Thursday [April 3, 1997] to use special tools to cut the protesters from the drums and get them off the roadway," according to a Nevada Highway Patrol spokesperson. [Refs. 34,35,36]

Actions to disrupt shipments without causing damage to the cask and its contents are not in and of themselves terrorist acts, but create an atmosphere in which violent actions could be encouraged, or that could mask the intentions of terrorists. Nor do such actions in and of themselves fit the traditional notion of sabotage, which implies disruptive action by workers or by persons posing as workers or other "insiders" to gain access to facilities or sensitive activities. Such actions should, however, be included in a terrorism/sabotage risk assessments because they may create the atmosphere for the same types of social and economic impacts as more violent terrorist/sabotage actions. Public perception of nuclear waste transportation risks combined with extensive media coverage means that such incidents could result in the same social amplification of stigma effects that would be expected with more violent terrorist/sabotage actions.

A further reason for including disruption events in a terrorism/sabotage risk assessment is the potential for such incidents to escalate into more violent actions. Organizers of mass demonstrations may be unwilling or unable to control the behavior of all participants, particularly if they believe the authorities have used excessive force in making arrests or employed what they believe are provocative crowd control weapons (such as water cannons, mace, or tear gas). More radical factions may participate in initially nonviolent demonstrations with the intention of provoking violent confrontations. The March, 1997 demonstrations in Germany appear to have contained the potential for actions that might have damaged the spent fuel casks and transport vehicles.

Finally, while the individuals or groups engaged in protest demonstrations may not be sympathetic to specific terrorist groups or their objectives, nonviolent protests may be exploited by terrorists planning to attack nuclear waste shipments. For example, terrorists might use a mass protest demonstration as a diversionary tactic to draw the attention of law enforcement authorities, creating enhanced opportunities for attack and escape. Terrorists might schedule an attack to coincide with a well publicized protest event in order to exploit the media attention focused on the protest. In a worst case scenario, terrorists might view hundreds or thousands of protesters as conveniently assembled victims for an intentional contamination incident.

Actions to induce severe accidents, possibly causing damage to the cask and release of contents. Experience with such events in the United States appears limited to one incident, a 1986 attempt to derail a train transporting spent nuclear fuel in Minnesota. One or more incidents associated with efforts to disrupt spent fuel shipments in Germany between 1995 and 1997 could also be categorized as attacks on infrastructure. Incidents of this nature may, or may not be, intended to cause a release of radioactive materials. Such incidents would not meet the NRC's definition of radiological sabotage, unless significant exposures or releases occurred or unless there was clear evidence that the action was intended to, and was capable of, causing a radiological threat to public health.

In November, 1984, Northern States Power (NSP) began shipping spent fuel from the Monticello reactor north of the Twin Cities to the General Electric storage facility at Morris, Illinois. NSP planned 30 or more dedicated train shipments over five years. This shipping campaign was highly visible because of opposition by the State of Wisconsin (including a court challenge and a rulemaking petition to the NRC), protest demonstrations by antinuclear groups in Minnesota and Wisconsin, and extensive media coverage, including a documentary produced by Wisconsin Public Television. The public controversy over the shipments was fueled by widespread public opposition in Minnesota and Wisconsin to DOE's Crystalline Repository Program. As directed by Congress in the NWPA of 1982, DOE was evaluating candidate sites in both states for a second geologic repository. Concern about the safety of the NSP shipments followed several years of public debate over the transportation impacts of a geologic repository. [Ref. 37]

On October 27, 1986, four days after the NRC refused the State of Wisconsin's petition for rulemaking on spent fuel transportation, a person or persons unknown removed a 39-foot long section of rail along the Burlington Northern route used for these shipments in Golden Valley, Minnesota. Near the tracks authorities found a sign reading "Stop Rad-Waste Shipments." This incident did not result in damage to the train transporting spent fuel. However, a Burlington Northern train hauling lumber, scheduled immediately prior to a train transporting spent fuel from Monticello, derailed at the site of the sabotage. The initial investigation focused on anti-nuclear activists and disgruntled railroad employees. To our knowledge, no one was ever arrested or charged in this case, and the current status of the investigation is uncertain. No group or individual claimed responsibility. A spokesperson for the Northern Sun Alliance, which had organized protests against the shipments, denounced the attempted sabotage. [Refs. 38,39,40,41,42]

The October, 1986 apparent attempted sabotage of a spent fuel shipment has not been studied in detail. Indeed, as far as the NRC's SSEL is concerned, the incident never happened. The incident is not reported in the relevant volumes of the SSEL. The omission of this incident is curious because Governor Tony Earl of Wisconsin, a state along the route, formally notified the Chairman of the NRC of his concerns about the reported sabotage incident and requested specific regulatory and investigative actions by the NRC.[Ref. 41] The omission of the incident from the SSEL is incongruous considering that the SSEL does report a February 4, 1985 telephone threat to NSP corporate headquarters warning that a group of anti-nuclear protesters would use a small airplane to stop a train carrying spent fuel from Monticello to Morris. [Ref. 43]

The MWR study team, apparently unaware of the 1986 Minnesota attempted derailment, hypothesized that one attack scenario developed by role-playing "might be an attack by a radical antinuclear group determined to end the nuclear program in the United States. Although bombing has been a preferred option by terrorists so far, the peculiar situation of waste transportation may render this option less effective than the manipulation of vehicles or transport routes since the same effect can be obtained at lower cost. Such manipulations are less costly and less detectable than the purchase and undetected emplacement of explosives. In addition, a radical antinuclear group is less likely to endanger "innocent" bystanders, but would be content with causing a major accident, even without a radioactive leak, and thereby jeopardize the continuation of the waste transportation program as a result of the social amplification of such an event." [Ref. 26]

The 1986 Minnesota incident is evidence of a credible risk of terrorism or sabotage against nuclear waste shipments, specifically damage to transportation infrastructure with the intent of causing an accident, although there is no clear evidence that the perpetrators intended to damage the shipping casks or cause a release of radioactive materials. The 1986 derailment attempt therefore does not constitute a worst case event for the purpose of repository transportation risk and impact assessment. In addition to this important omission of the Minnesota incident from the SSEL, two significant instances of railroad sabotage against passenger trains and one foiled terrorist plot against highway bridges and tunnels suggest parameters for specification of credible maximum severe attack scenarios.

"Nevada's worst rail disaster," a Southern Pacific train wreck at Harney, west of Carlin, on August 12, 1939, was caused by sabotage. Railroad spikes "in perfect condition evidently had been removed and the diesel-powered City of San Francisco, among the most luxurious trains of the day, became a macabre pile of twisted metal in an isolated, rocky canyon. ... three locomotives and 10 of the trains 14 cars were derailed. Five of them plunged into the river." Twenty-four people were killed and 114 injured. Whoever was responsible had selected a location designed to cause maximum damage, had tampered with the rails less than four hours before the wreck, and had wired the rail gap "to show a clear-track signal." The train was traveling at 60 miles per hour at the time. State and Federal investigations concluded that sabotage caused the Harney disaster, but the crime was never solved. [Ref. 44] A DOE contractor study, part of DOE's larger effort to "determine the feasibility of rail shipment of spent fuel to a proposed repository at Yucca Mountain, Nevada," identified the 1939 Harney disaster as "one of three past Nevada accidents that represent worst-case scenarios of potential railroad mishaps." [Ref. 45]

On October 9, 1995, the Sunset Limited, a 10-car Amtrak train carrying 248 passengers and 20 crew members, derailed near Hyder, Arizona. One person died and over 70 were injured. The train had been traveling at 50 miles per hour when it derailed on a trestle at about 1:00 a.m. Two locomotives and four cars fell 30 feet into a dry creek bed. Spikes had been removed from ties holding a 19-foot section of rail, a metal bar connecting two rails had been removed, and the open joint had been wired to circumvent an electronic warning system. A typewritten note found near the scene took credit on behalf of a group calling itself the Sons of the Gestapo. The note criticized Federal and State law enforcement agencies and mentioned the Waco, Texas and Ruby Ridge, Idaho, confrontations. The derailment remains under investigation by the FBI. [Refs. 46,47,48,49]

In addition to these railroad sabotage incidents, a significant terrorist prevention should be noted. On October 1, 1995, a Federal jury in New York City convicted Sheik Omar Abdel Rahman, a Muslim religious leader, and nine other militant Muslims of conspiracy to carry out a massive campaign of terrorist bombings and assassinations. Prosecutors charged the group with planning "a cataclysmic 'day of terror': five bombs that were to blow up the United Nations headquarters, the Lincoln and Holland tunnels, the George Washington Bridge and 26 Federal Plaza, the Government's main office building in New York." The goal of the attacks, using bombs made of diesel oil and fertilizer, was to "kill hundreds of people and force Washington to abandon its support for Israel and Egypt." [Ref. 50] The George Washington Bridge is on Interstate 95, a major gateway from Manhattan, Long Island, and

New England into New Jersey for trucks traveling I-95 to the south and I-80 to the west. The George Washington Bridge has previously been used for truck shipments of irradiated reactor fuel and plutonium from Brookhaven National Laboratory to the Savannah River Plant in South Carolina. [Ref. 51] The George Washington Bridge could potentially be used for truck shipments of spent fuel from Connecticut reactors to a storage or disposal site in Nevada. [Ref. 52]

A comprehensive terrorism/sabotage risk assessment must consider that: (1) transportation infrastructure used by spent nuclear fuel shipments could be attacked by a range of adversaries including antinuclear activists, political terrorists, and transportation industry personnel; (2) rail and/or highway infrastructure could be targeted; and (3) attacks could occur at urban and/or rural locations. Attacks on rail infrastructure at remote locations may be especially attractive to perpetrators because of greater opportunities to isolate the target, carry out the attack, and escape.

Lessons learned from previous incidents of infrastructure sabotage, particularly insights into the intentions and capabilities of the attackers, must be applied to the assessment of potential attacks on infrastructure used by nuclear waste shipments. These lessons include: (1) attacks on trains, bridges, and tunnels without warning that show a willingness if not an intention to kill, maim, and terrify tens, hundreds, or thousands of people at a time; (2) the attackers technical expertise, at least in the case of the rail sabotage events, has been sufficient to defeat existing technical countermeasures, such as electronic warning systems; (3) the attackers success in causing accident conditions such as derailments at speeds of 50-60 miles per hour, followed by 30 foot drops, demonstrates their ability to at least challenge the containment performance standards of NRC-certified shipping containers; and (4) future attacks on infrastructure may be carried out with the use of home-made explosives and do not require the procurement of exotic weapons to be successful.

A comprehensive terrorism/sabotage risk assessment must consider a range of responses by the cask and its contents to the forces generated by an attack on transportation infrastructure components. Such a comprehensive assessment is difficult because of the absence of full-scale physical test results for the new cask designs that will be used for repository shipments. Under such conditions as hypothesized above, there may be no significant likelihood of a loss of cask shielding or containment. For example, the simple derailment of a single rail cask car, even at a maximum normal operating speed of 50 to 70 miles per hour, would probably not, in our opinion, result in a significant radiological exposure or release of contents, absent unexpected human factors. On the other hand, high-speed derailment of a rail cask car or cars could result in a significant radiological exposure or release of contents if coupled with other dangerous conditions, such as collision with a massive rock face or outcrop, collision of the cask side midpoint against a bridge support column, fall from a high bridge or trestle, tumble down a steep canyon wall, or rupture of a collocated petroleum or natural gas pipeline. The derailment and pile-up of a dedicated train could subject a cask to considerable impact and crush forces from the locomotives and other casks. In addition, supplemental attack tactics like the use of explosives to create a rock slide or collapse a rail tunnel could also subject casks to severe crush forces.

Attacks on shipping casks that are clearly intended to cause a release of radioactive materials. There is no experience with such incidents. Past analyses of the consequences of terrorist attacks by NRC and DOE contractors focused upon direct attacks with high-energy explosive devices, specifically military demolition charges, although to date there have been no such attacks on spent fuel shipping casks. Peer reviewers and critics of the DOE and NRC studies have suggested the possibility of attacks on casks using similar weapons under different circumstances, other military weapons, commercial explosives, and massive truck bombs. We assume, as have previous analyses, that incidents of this nature are intended to cause a release of radioactive materials and that such incidents are credible. Such incidents would meet the NRC's definition of radiological sabotage.

The U.S. Army Ballistic Research Laboratory (BRL) reviewed the choice of weapons assumed in the DOE and NRC contractor studies in 1983. BRL's comments are instructive regarding both past and future assessments of attacks using military explosives. According to the BRL review, "Since release of contaminants depends on breaching the cask and disrupting the fuel rods, the threat must have adequate penetration. Considering generic classes of HED [High Energy Devices] threats, shaped charges generally have the highest penetration for a fixed weight. (For example, a well-designed charge weighing as little as 5 lbs. could penetrate a cask, but in such a case the hole diameter and the amount of fuel disrupted would be small.) Hence, the shaped charge approach provides the minimum weight HED necessary to breach a cask and disrupt fuel. Within the weight constraints implicit in the scenario, a shaped-charge is the device of choice to meet the objective." [Ref. 53]

BRL concluded that the M3A1 military demolition shaped charge selected by Sandia as the reference terrorist weapon was "an appropriate threat simulant, given considerations of weight, penetration, and availability," and that Sandia's "penetration results for the M3A1 into the IF-200 cask are consistent with that HED's known performance." The M3A1 weighs 40 pounds, contains 27 1/2 pounds of Composition B high explosive, and " is primarily used to produce craters in soil, rock, pavement, and ice targets." BRL noted that "fragmentation and blast effects from the M3A1 might be significant in the urban scenario. This device projects lethal fragments over 100m." [Ref. 53]

The BRL analysis found that the M3A1 was capable of penetrating at least one cask wall of, and damaging the fuel rods inside of, any of the four available truck cask designs [the NFS-4, NLT 1/2, TN-8, and TN-9]. The widely used NFS-4 was the reference target in the Sandia full-scale tests. However, Sandia used the M3A1 against an obsolete GE IF-200 cask because it was available for destructive testing, in spite of the fact that it had "thicker walls than NFS-4 and would be more difficult to perforate." Because the NFS-4 has "about four inches less lead and an inch less of steel along its diameter," BRL concluded that "complete cask perforations should occur if the M3A1 attacks the NFS-4." [Ref. 53]

BRL also pointed out that "if one wished to modify the M3A1 to produce more fuel release, the design should be changed to increase hole diameter more than to increase penetration. Design modifications could employ modern liner and explosive technology to increase the jet diameter and hence increase fuel rod damage. Another method of attack would be to breach the cask with a shaped-charge and then insert several pounds of HE [high explosive] into the resulting crater, thus increasing damage to the fuel rods and dissemination to the surrounding area." [Ref. 53]

Other reviewers of the NRC's 1984 proposed rule argued that terrorists might attack a cask more effectively with commercial rather than military explosives. The Sierra Club Radioactive Waste Campaign argued: "Sabotage of an irradiated fuel shipment could be relatively fast and simple, with explosive devices that are commercially available. Because of its long association with the military, Sandia Laboratories tested the military M3A1 shaped charge device, weighing 45 pounds." According to the Sierra Club reviewers, "effective devices weighing much less, on the order of 1 1/2 pounds are available. A conical-shaped charge, with an incendiary device, ... would be much more effective. Such a device could pierce 14 inches of metal, thus entering and exiting a shipping cask. The interior of the cask could be heated to 1,649 degrees C. This would ignite the zirconium cladding, further raising the temperature until the oxygen in the cask was exhausted. These temperatures would vaporize certain radionuclides, such as cesium. These devices [conical shaped charges] are commercially available and in use in well-drilling, spaceship, and other applications. They are available to secular regimes such as Iran. We therefore disagree with the NRC assumption that tens to hundreds of pounds of explosives are needed to disperse radioactivity from a shipping cask." [Ref. 54]

The issue of terrorist attacks using armor-piercing weapons was raised at a March 23, 1989, U.S. DOE public hearing in Reno on the Yucca Mountain Site Characterization Plan. A Nevada resident testified: "Terrorists or saboteurs using military weapons, especially man-portable armor-piercing anti-tank rockets or missiles, could threatened or actually cause the release of large amounts of lethal radiation from one or more of the cask containers at almost any point along the transport routes in or out of Nevada." The speaker provided for the record detailed information on armor penetration capabilities of ten man-portable weapons systems. He also addressed the availability of anti-armor weapons: "Modern anti-armor portable weapons are widely distributed in large numbers. Whether through direct supply by a weapon-producing nation or by theft, blackmail, treason, or purchase on the world arms black market, they can and have fallen into enemy, unfriendly, or terrorist hands. To summarize, the proposed transportation of high-level waste to Yucca Mountain across public highways in Nevada would create a virtual nuclear shooting gallery for terrorists armed with any of these weapons." [Ref. 55]

NWPO staff and contractors were present at the Reno hearing, but did not testify on the issue pending completion of scoping studies on cask vulnerability to explosives, NRC safeguards regulations, and DOE physical protection plans. DOE has never publicly responded to the concerns raised at the March, 1989 hearing in Reno. Six months previously, NWPO had proposed in the ACR 8 Report [Ref. 2] an ambitious plan for an independent assessment of sabotage and terrorism risks following the recommendations of the Transportation Needs Assessment. The NWPO terrorism study project was scaled back and finally deferred in early 1990 due to budget cuts, and none of the research products were published in final form.

In February, 1990, NWPO contractors prepared an internal document outlining key issues to be studied in detail if funding became available. The outline identified three types of attacks involving high energy explosives: capture of shipment with intent to ransom cask (threat to blow up cask); capture of shipment with intent to cause radiological contamination; and attack on shipment with intent to cause radiological contamination. Four types of weapons were identified: man-portable explosives, remote-controlled mines, massive truck bombs, and armor-piercing guided missiles. The outline also identified future social and political conditions that might increase the probability of attacks with high energy explosives: (1) repository proceeds in spite of intense local/state/regional opposition to siting and transportation impacts; (2) widespread social/economic/political turmoil in the U.S. creates opportunities for extremist political organizations and/or criminal enterprises; and (3) U.S. involvement in declared or undeclared war with foreign country or countries. [Ref. 56]

A 1980 NRC contractor study reported: "Pronuclear activists and the nuclear industry believe radioactive materials, in general, are highly overrated as targets for acts of sabotage to produce widespread death and destruction or for acts of theft for purposes of weapons fabrication. A crude nuclear device requires technical expertise to construct, which is usually not available in today's terrorist organizations. Such terrorist groups would find it easier to try to disperse radioactive materials through other means, such as by dynamite. Still, it has not been the pattern of terrorist groups in the past to kill large numbers of people or to cause large numbers of lingering deaths. Terrorist groups have typically used violent means to make a political statement. 'Terrorists want a lot of people watching, not a lot of people dead.'" [Ref. 24]

Nuclear industry views and the views of most DOE and NRC officials and technical experts appear to have changed little over the past two decades. The authors agree that attacks to capture and divert spent fuel for purposes of fabricating a nuclear bomb currently appear so unlikely that they could be omitted from a repository risk assessment. The willingness of terrorists to kill large numbers of people, however, has been demonstrated in the World Trade Center and Oklahoma City bombings. Many terrorism experts believe that while the number of attacks are seemingly decreasing, the lethality of attacks is seemingly increasing. One international risk management specialist summarized the global situation in 1996: "Terrorism persists [after the end of the cold war] and although the total volume of incidents may wobble from year to year, incidents of large scale indiscriminate violence - attacks calculated to kill in quantity, have become more common." [Ref. 57]

The FBI's Terrorism in the United States: 1995 reported: "In the past year, the country witnessed the re-emergence of spectacular terrorism with the Oklahoma City bombing.

Large-scale attacks designed to inflict mass casualties appear to be a new terrorist method in the United States." The Oklahoma City bombing reflected a "general trend in which fewer attacks are occurring in the United States, but individual attacks are becoming more deadly." The FBI voiced concern about terrorist interest in advanced technologies and improving terrorist capabilities regarding electronic communications, computer databases, and analysis of past events which "could prompt future terrorists to plan their attacks with greater care." The FBI also noted "a chilling trend" in continued terrorist interest in unconventional weapons such as biological agents, concluding that "terrorists and other criminals may consider using unconventional weapons in an attack here sometime in the future." [Ref. 58]

A comprehensive terrorism/sabotage risk assessment must consider direct attacks on casks with a range of high-energy explosive devices, with and without capture of the cask, by a range of potential adversaries with widely differing objectives and capabilities. Adversaries capable of capturing and controlling the cask and transport vehicle could attack the cask with a variety of devices, including military demolition charges, commercial conical shaped charges, commercial cutting charges, or a massive diesel fuel and fertilizer truck bomb. Attackers may well be able to control the cask for a period of 30 to 120 minutes, for example, by threatening to kill the driver, train crew, escorts, or other hostages. Given sufficient time, the attackers may be able to increase the effectiveness of their weapons, for example, by removing an impact limiter and applying explosives directly to the cask closure lid, by removing the personnel barrier and applying explosives around the middle of the cask, or by applying multiple charges at different points.

Adversaries could use a variety of weapons to attack a cask without capturing it. Remote-controlled or self-detonating mines could be used against either truck or rail shipments. Man-portable mortars, rifle-fired grenades, recoilless guns, and a variety of anti-tank missiles could be used to attack shipments while in transit, in some cases from a distance of hundreds or thousands of meters. It is also conceivable that adversaries could obtain and use military aircraft or attack vehicles armed with bombs, missiles, or other powerful weapons. The risk of attacks involving stolen or otherwise diverted military weapons systems must be given special attention considering the number and nature of military installations in Nevada and along the transportation corridors to Nevada.

A number of different adversary profiles must be considered. Potential perpetrators include domestic and foreign political terrorist groups and individuals, radical antinuclear activists, disgruntled nuclear or transportation industry employees, organized criminal enterprises, and foreign governments. The individuals actually carrying out attacks may have much greater technical expertise than assumed by those compiling their profiles. The attackers may very well be current or former military or civilian explosives experts. During wartime, declared or undeclared, the attackers could be enemy military personnel or specially trained agents. Different combinations of weapons capabilities and attacker capabilities and objectives could result in greater or lesser consequences.

A complete assessment of the full range of options for direct attacks on casks with high-energy explosives is clearly beyond the scope of this paper. Indeed, the authors' major conclusion is that a comprehensive terrorism/sabotage risk assessment will require a significant combined effort by DOE, the NRC, the State of Nevada, and affected stakeholders. Available information, however, lead us to conclude that a sufficient repository transportation risk assessment must, at a minimum, consider 2 scenarios: 1) an attack in which the cask is captured, penetrated by an emplaced explosive device, and releases at least one percent of its radioactive contents; and 2) an attack in which the cask is perforated by an anti-tank missile and releases at least one percent of its radioactive contents. The first scenario would essentially involve updating the analyses conducted by DOE and NRC contractors in the late 1970s and 1980s, with due consideration of various reviewers' criticisms. The next section of this paper describes an approach to specifying and assessing the consequences of an attack with man-portable armor piercing weapons.

GUIDELINES FOR ASSESSING THE CONSEQUENCES OF TERRORIST ATTACKS EMPLOYING ANTI-TANK WEAPONS

The consequences of a successful terrorist attack involving armor-piercing weapons or other high energy explosive devices will constitute one of the most important components of a comprehensive assessment of the risk of terrorism against repository shipments. A new consequence assessment is necessary because the assessments conducted by DOE and NRC contractors in the late 1970s and early 1980s are methodologically deficient and based on assumptions that do not accurately represent the types of shipments likely to be made to a repository (or storage facility) in the first decade of the 21st century and the threats those shipments will face.

A meaningful terrorism consequence assessment must employ assumptions consistent with information about the weapons currently available, and weapons likely to become available, to potential adversaries and the technical and tactical expertise of potential adversaries. It must employ assumptions consistent with current DOE spent fuel and high-level waste transportation plans, particularly as those plans determine the characteristics of the shipping casks which will be used and the characteristics of the spent fuel shipped. In order to be legally sufficient for purposes of the Yucca Mountain Environmental Impact Statement, a new and comprehensive terrorism consequence assessment must employ credible worst case assumptions about the timing and location of a potential attack and weather conditions during and after the attack, consistent with characteristics of the routes most likely to be used for shipments to a repository or storage site in Nevada.

Selection of Reference Weapon. British strategic affairs journalist Brian Beckett wrote one of the earliest references to the potential use of anti-tank missiles against nuclear waste shipments. In a discussion of the difficulties terrorists would face in fabricating a nuclear weapon from stolen fissile material, Beckett noted: "A more obvious danger is posed by nuclear waste. The likelihood of theft is small because nuclear waste is usually stored and transported in large metal and concrete drums which would be extremely difficult to remove.

Instead, nuclear waste could be blown up in transit to spread radioactive contamination in the air. In 1980, the London Observer reported that a demonstrator carrying a dummy rocket-launcher had walked onto a railway platform where a train hauling nuclear waste was due to pass - according to a subsequent statement from British Rail, regulations did not forbid passengers carrying rocket-launchers from going onto station platforms." [Ref. 59]

There has been little discussion of the use of anti-tank missiles against SNF shipping casks in the official debate over nuclear waste transportation safeguards regulations since the 1980s. Even then, government and university experts, such as British security specialist Richard Clutterbuck, have minimized the public health and environmental consequences of successful penetration of the cask wall unless an attack with anti-tank weapons was accompanied by a prolonged, engulfing, high-temperature fire. "Nevertheless a well-sited attack or hijack of a nuclear flask could cause serious disruption by closing a bottleneck or (with the case of fire creating a fall-out of radioactive dust) evacuation of a large area for a considerable time while testing, clearing and removal is completed." [Ref. 60]

The most detailed discussion of potential terrorist use of anti-tank missiles occurred at the March 23, 1989, DOE public hearing in Reno, Nevada, on the site characterization plan for Yucca Mountain. Testimony there addressed not only general concerns, such as the widespread availability of shoulder-fired weapons and the armor-piercing capability of shaped-charge warheads, but specific weapons capabilities. Heavier wire-guided missiles such as the U.S. TOW and the French/NATO Milan were identified as terrorist weapons of choice because of their armor penetration, effective range, and proven battlefield performance around the world. [Ref. 55]

We recommend that a new consequence assessment assume portable anti-tank missiles as the reference weapon. First and foremost, virtually all of the anti-tank missiles evaluated in the following discussion have warheads capable of completely perforating a truck cask and its spent fuel cargo and are capable of deeply penetrating (if not completely perforating) a rail cask and damaging the spent fuel inside. These weapons are designed to hit moving targets at a distance of 30 meters or more, eliminating the need to capture the cask, and facilitating selection of optimal attack times and locations. Portability of these weapons allows further flexibility in attack planning, including use of multiple warheads, and in escape planning. Many different types of anti-tank missiles are currently being produced in many different countries, and in some instances, tens to hundreds of thousands of units of particular designs have been produced. Most older weapons have been used in battle, and newer versions have been extensively field tested. The limitations and deficiencies of specific weapons (backblast effects, operator error in guidance control, guidance system failure, fuse and warhead failure) are known and can be factored into the consequence assessment. [Ref. 61] Potential adversaries could obtain anti-tank weapons through a variety of channels, including terrorist state-sponsorship, purchase, theft, or blackmail.

Weapons Availability and Capabilities. Many portable anti-tank missiles currently available to potential attackers apparently have armor penetration capabilities equal to, or exceeding, the M3A1 military demolition charge used as the reference weapon in the Sandia and Battelle test program. Detailed performance data on the latest versions of most systems are classified, for obvious reasons. Given the general trend of improved armor penetration capability over the past four decades, it should be assumed that even more effective weapons will become available over the next four decades when repository shipments occur.

Table 5 summarizes publicly available performance data on some of the better known anti-tank missiles currently in use. It is useful to segment the discussion of these weapons, their availability, and their capabilities into three chronological groupings.

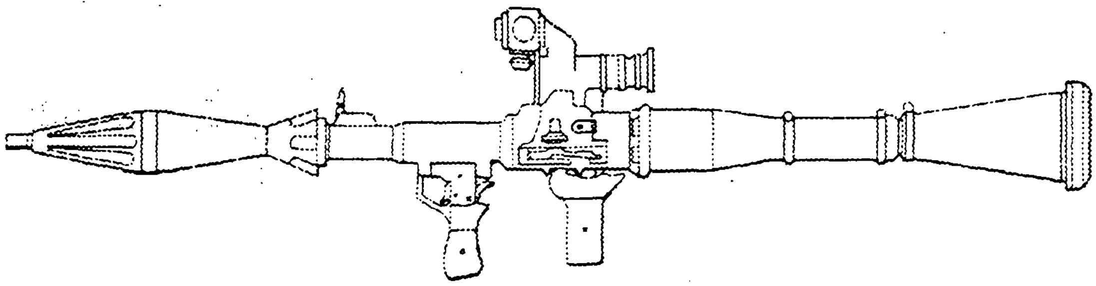
Table 5

Man-Portable Anti-Tank Weapons				
Weapon/Country	**Weight**	**Range**	**Warhead Dia./Wt.**	**Armor Penetration**
Milan Anti-Tank Missile France	32 kg	2000 m	133 mm/3.12 kg	>1000 mm
Eryx Anti-Tank Missile France	21 kg	600 m	160 mm/ 3.8 kg	900 mm
Panzerfaust 3 Anti-Tank Launcher/ Germany	13 kg	300 m	110 mm/NA	> 700 mm
Folgore Anti-Tank System Italy	21 kg	4500 m	80 mm/3 kg	> 450 mm
Apilas/South Africa	9 kg	330 m	112 mm/NA	> 720 mm
RPG-7 Anti-Tank Launcher/Soviet Union	11 kg	300 m	85 mm/NA	330 mm
C-90-C Weapon System Spain	5 kg	200 m	90 mm/NA	500 mm
AT-4 Anti-Tank Launcher Sweden	7 kg	300 m	84 mm/NA	> 400 mm
Carl Gustav M2 Recoilless Gun/Sweden	15 kg	700 m	84 mm/NA	> 400 mm
LAW 80 Anti-tank Launcher/ U.K.	9 kg	500 m	94 mm/NA	700 mm
M72 66mm Anti-tank Launcher/USA	4 kg	220 m	66 mm/NA	350 mm
SMAW/USA	14 kg	500 m	83 mm/NA	> 600 mm
AT-8 Bunker Buster/ USA	8 kg	250 m	84 mm/NA	NA
Superdragon Anti-tank Missile/USA	17 kg	1500 m	140 mm/10.07 kg	> 500 mm
TOW 2 Anti-tank Missile USA	116 kg	3750 m	127 mm/28 kg	> 700 mm
Javelin AAWS/M/USA	16 kg	2000 m	127 mm/NA	> 400 mm
Source: Reference 62				

First, the earliest shoulder-fired anti-tank weapons, from their origins in World War II through the 1950s, were recoilless guns and tube-launched rockets that could deliver a warhead capable of piercing a few inches of modern armor plate. These weapons include the original German Panzerfaust series, the U.S. Bazookas, and the Soviet RPG-2. [Ref. 63] Long since abandoned by modern armies and irregular forces, such weapons could be available from military museums or private weapons collections. It seems unlikely that knowledgeable adversaries would use such weapons to attack a shipping cask, but if skillfully deployed, these weapons could damage or breach certain cask designs.

The second group of anti-tank weapons, capable of penetrating a foot of armor or more, evolved in the 1960s and were used extensively through the 1980s. Important examples are the Soviet RPG-7 and U.S. M72 LAW rocket launchers; the Swedish Carl Gustav M2 recoilless gun; and the first man-portable guided missiles: the French SS 10, SS 11, and Entac; the German Cobra; and the British Vigilant and Swingfire. The new weapons penetrated Cold War arms markets as quickly as they penetrated tank armor. By 1969, 116,000 Entacs had been delivered to six countries, and 120,000 Cobras had been sold to 18 countries. [Ref. 63]

The Soviet RPG-7, shown in Figure 16, first appeared in the early 1960s. Capable of penetrating a foot of armor at 300 to 500 meters, the RPG-7 and its successors were widely used by the former Warsaw Pact countries and by Soviet-supplied guerrilla forces in Africa, Asia, and Latin America. China, Czechoslovakia, Egypt, Iraq, Pakistan, and other countries made and sold it. [Ref. 62, 64] Early versions were "easily short-circuited by hanging chicken wire outside the target, but this defect was rapidly overcome and present day fuses are reliable." [Ref. 62]



Specifications:

Caliber of warhead: 85 mm	Maximum velocity: 300 m/sec
Weight in firing order: 10.15 kg	Penetration of armor: 330 mm
Length of launcher: 950 mm	Manufacturer: State arsenals, Russia
Max. range: 500 m stationary target 300 m moving target	

Left and right side view of an Afghan Mujahedeen guerilla taking aim with an empty RPG-7, and showing the sights and pistol grip.

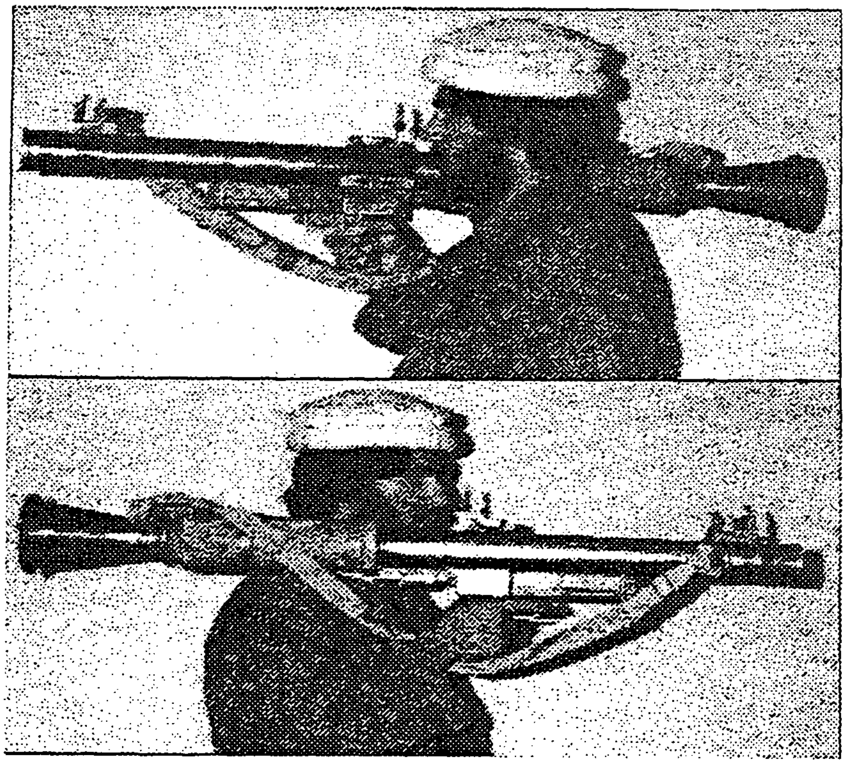
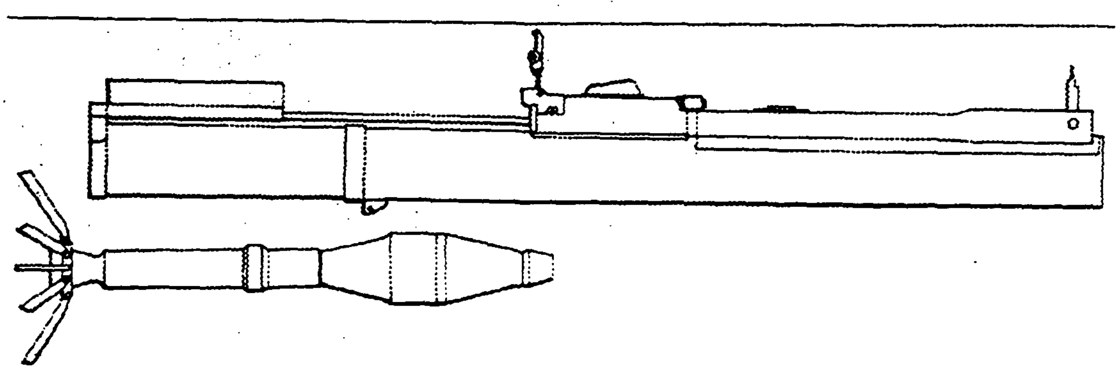


Figure 16 reproduced by permission of the Publisher from Ian V. Hogg, Infantry Support Weapons: Mortars, Missiles, and Machine Guns, Greenhill Military Manual, No. 5, (1995) Greenhill Books, Lionel Leventhal Limited, London.

Figure 16. Schematic, Specifications and Photos of RPG-7 Anti-tank Missile

The U.S. M72 66mm LAW (Light Anti-armor Weapon), shown in Figure 17, was also developed in the 1960s. Ian Hogg describes it as "a revolutionary idea: a pre-packaged rocket which could be fired and the launcher then thrown away."[Ref. 62] Like the RPG-7, the M72 is capable of penetrating a foot of armor, but its effective range is only 170 to 220 meters. Manufactured by Talley Industries in the U.S. and under license in Norway, it not only became a NATO standard but was copied and produced in Czechoslovakia and Russia (as the RPG-18 and RPG-26). Early versions were frequently inaccurate, corrected by an improved sight and a more powerful rocket motor. [Ref. 62]

M72 66mm Anti-tank Missile



Specifications:

Caliber of warhead: 66 m

Weight in firing order: 3.45 kg

Length of launcher: 980 mm

Maximum range: 200 m/sec

Maximum velocity: 200 m/sec

Penetration of armor: 350 mm

Manufacturer: Talley Industries, USA

Figure 17a: Schematic and Specifications of the M72 66mm Anti-tank Missile

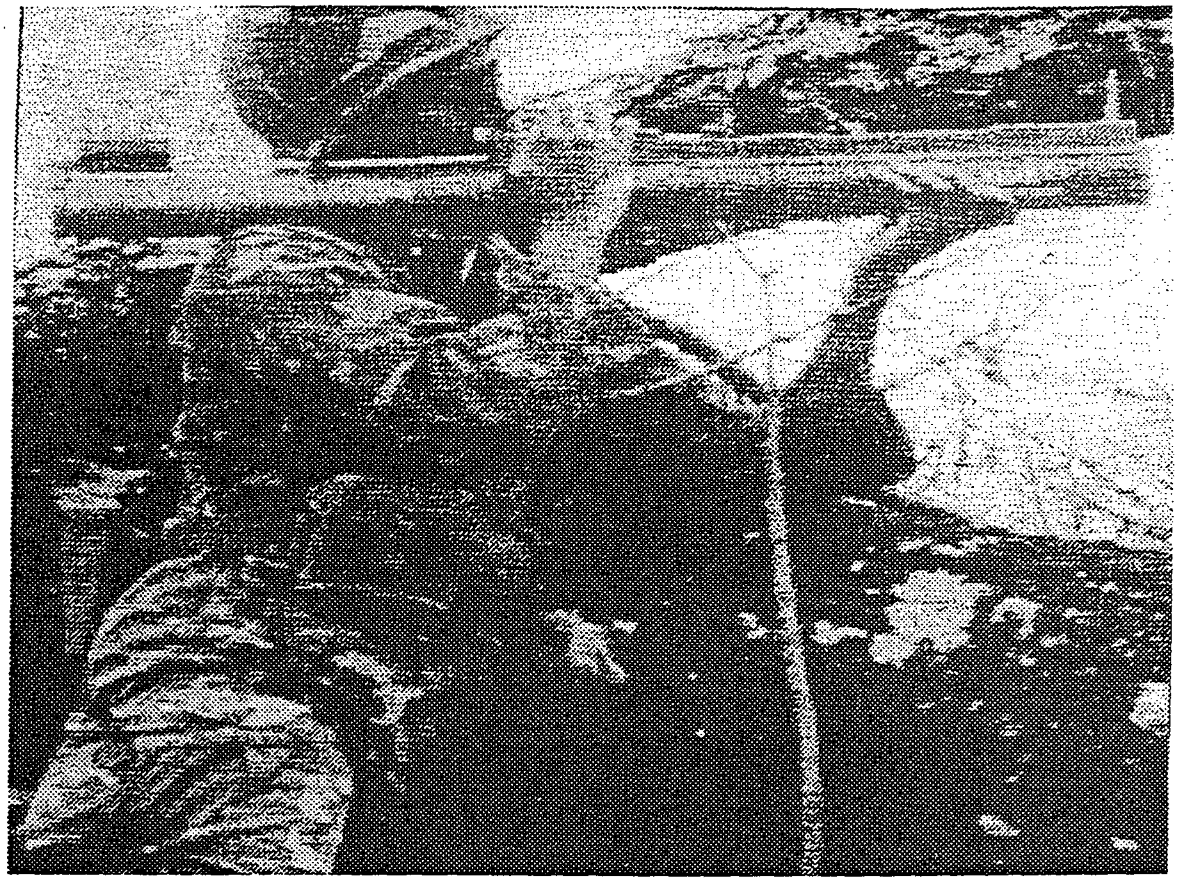


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Figure 17b. Photo of the M72 66mm Anti-tank Missile

The third group of weapons, advanced guided missiles capable of penetrating half-a-yard to a yard or more of armor plate, appeared in the 1970s and 1980s and are currently in use around the world. By the mid-1980s, Jane's Weapons Systems listed more than twenty varieties being produced by a dozen countries. [Ref. 65] Important examples are the U.S. Dragon, Superdragon, and TOW (Tube-launched, Optically-tracked, Wire-guided) anti-tank missiles and the French Milan and Eryx anti-tank missiles.

The U.S. Dragon was introduced in 1971, was redesigned twice, and evolved into the present Superdragon by 1990. (See Figure 18) The current version is capable of penetrating 18 inches of armor at a maximum effective range of 1,500 meters. Manufactured by McDonnell Douglas, the Dragon was adopted by the U.S. Army and Marine Corps and is used by at least 10 other countries. [Ref 63.] The Dragon saw limited use in Operation Desert Storm. One authoritative source reports that "Iraq is believed to have captured Dragons from Iran." [Ref. 66] The Dragon guidance system has been criticized for requiring excessive gunner control, inaccuracy in general, and some early versions suffered recurrent rocket thruster failure. [Ref. 65, 66] In March, 1997, a woman exploring caves near Fallon, Nevada, found a Dragon missile launcher. Noting the 1977 date on the launcher tube, the Churchill County Sheriff speculated that the device could have been obtained through the surplus arms market or could have been someone's personal souvenir. [Ref. 67]

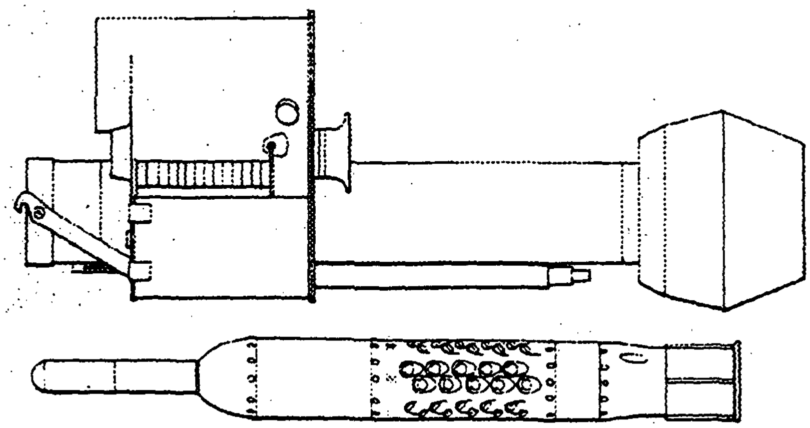

Figure 18a: Schematic of the Superdragon Anti-tank Missile

Specifications:

Guidance: Semi-automatic, wire
Warhead diameter: ca 140 mm
Launch unit weight: 6.9 kg
Missile weight: 10.07 kg
Missile length: 852 mm
Max. effective range: 1500 m
Max. velocity: ca 200 m/sec
Penetration of armor: >500 mm
Manufacturer: McDonnell Douglas Aerospace, USA

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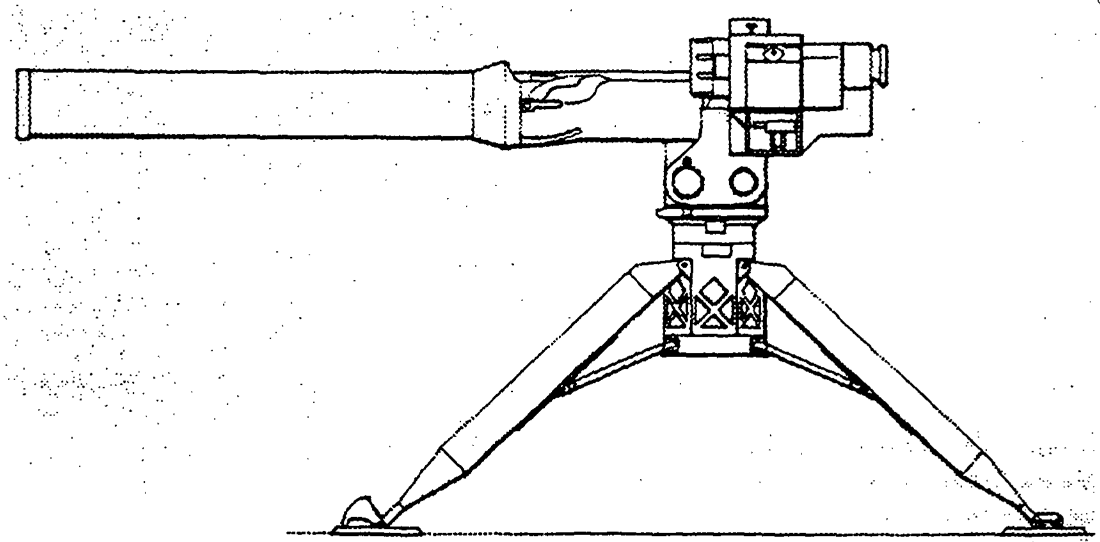
Figure 18b: Specifications and Photo of the Superdragon Anti-tank Missile

The U.S. TOW anti-tank missile of Iran-Contra fame was introduced for service in the U.S. Army in 1970. Current versions are capable of penetrating more than 30 inches of armor, or "any 1990s tank," at a maximum range of more than 3,000 meters. It can be fired by infantrymen using a tripod, as well from vehicles and helicopters, and can launch 3 missiles in 90 seconds. Manufactured by Hughes Aircraft Company, the TOW is "the most widely distributed anti-tank guided missile in the world," with over 500,000 built and in service in the U.S. and 36 other countries. The TOW has extensive combat experience in Vietnam and the Middle East. Iran may have obtained 1,750 or more TOWs and used TOWs against Iraqi tanks in the 1980s. [Ref. 66]



Specifications:

Guidance: Semi-automatic, wire
Warhead Diameter: 127 mm
Launch unit weight: 87.5 kg
Missile weight: 28 kg
Missile length: 1174 mm

Max. effective range: 3750 m
Max. velocity: 200 m/sec
Penetration of armor: >700 mm
Manufacturer: Hughes Missile Systems, USA

Figure 19a: Schematic and Specifications of the TOW 2 Anti-tank Missile

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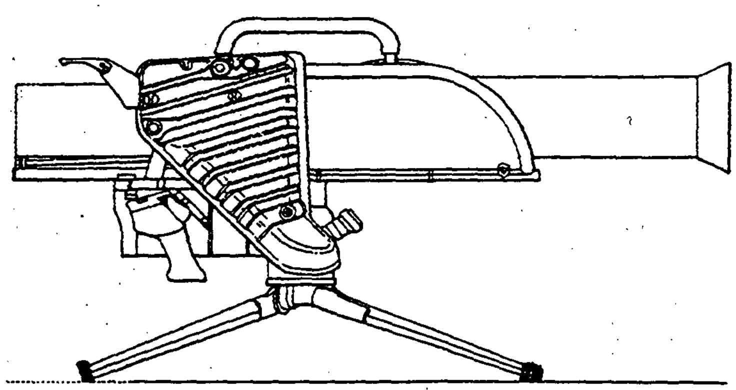
Figure 19b. Photo of the TOW Anti-Tank Missile

The Milan anti-tank missile, developed by a French-led consortium, is considered "one of the most successful" man-portable guided missiles. The current version, the Milan 3, is capable of penetrating over 40 inches of armor at a maximum range of 2,000 meters. Manufactured by Aerospatiale-Missiles in France and under license in Britain, Germany, and India, "several tens of thousands have been produced, it is used by most NATO and several other armies, and the basic principle has been widely copied." [Ref. 62] The Milan is noted for its sight-on-target guidance system, its night vision sight, and its ability to defeat reactive armor with an extended explosive probe. In addition to the NATO forces, Milan is used by Iran, Iraq, Pakistan, and India. The Milan has extensive combat experience in Chad, the Iran-Iraq Gulf War, and the Falklands/Malvinas War between Great Britain and Argentina. [Ref. 55, 62]



Specifications:

Guidance: Semi-automatic, wire	Missile length: 1200 mm
Warhead diameter: 133 mm	Max. effective range: 2000 m
Warhead weight: 3.12 kg	Max. velocity: 210 m/sec
Launch unit weight: 16.9 kg	Penetration of armor: >1000 mm
Missile weight: 11.91 kg	Manufacturer: Aerospatiale-Missiles, France

Figure 20a: Schematic and Specifications of the MILAN Anti-tank Missile

Figures 20a and 20b reproduced by permission of the Publisher from Ian V. Hogg, Infantry Support Weapons: Mortars, Missiles, and Machine Guns, Greenhill Military Manual, No. 5, (1995) Greenhill Books, Lionel Leventhal Limited, London.

Figure 20b. Photo of the Milan Anti-tank Missile

We recommend that a new consequence assessment evaluate a terrorist attack using anti-tank weapons at least equal to current versions of the U.S. TOW and French Milan missiles. For purposes of scenario development, the reference weapon should be assumed to be man-portable, operated by one to three persons, capable of firing up to three missiles, with a minimum range of 75 meters and a maximum range of 2,000. The reference weapon should be assumed capable of penetrating 40 inches or more of armor plate steel, with a hole diameter of 3 to 6 inches. Based on U.S. Army experience with the TOW, a hit-probability of 90 percent or greater should be assumed.

Selection of Reference Shipping Cask Designs. The shipping casks used for repository shipments will have different design configurations and use different structural and shielding materials than the casks that were assumed in the DOE and NRC consequence assessments. Some of these differences may make them more vulnerable to attack with armor-piercing weapons or high-energy explosives.

DOE has not formally selected cask designs for repository shipments. Under the provisions of DOE's current transportation privatization proposal, cask procurement decisions ultimately may be made by transportation service contractors. Moreover, with one exception, the cask designs usually assumed for repository shipments have not yet completed the NRC certification process.

Based on the information available as of June, 1997, it is probable that the majority of truck shipments to a repository, assuming repository operations begin in 2010, will use GA 4 and GA 9 casks or new high-capacity casks of similar design. If Congress directs DOE to begin shipments to an interim storage facility in or about the year 2000, currently licensed casks, or enhanced-capacity casks based on current designs would probably be used for the majority of truck shipments during the first five years of operation, after which GA 4/9 casks or similar designs would carry most SNF cargoes. [Ref. 9]

Based on the information available as of June, 1997, it is probable that the majority of rail shipments to a repository, assuming repository operations begin in 2010, will use new high-capacity casks similar to either the currently licensed NAC-TSC or the proposed design for the large MPC Rail Transporter. If Congress directs DOE to begin shipments to an interim storage facility in or about the year 2000, it is likely that relatively few rail shipments would be made during the first five years of operation, and those shipments would use currently licensed casks, the IF-300 and the NAC-TSC, to the extent of their availability. [Ref. 9]

The new-high capacity truck and rail casks assumed for repository shipments carry payloads three to four times greater than the currently licensed NAC LWT and IF-300 casks. The increase in truck cask capacity results primarily from lower shielding requirements for old, cooler SNF and from the use of different shielding materials. The increase in rail cask capacity results partly from lower shielding requirements for old, cooler SNF and the use of different shielding materials, but also from an overall increase in loaded cask weight to 125 tons, opposed by the Association of American Railroads because it exceeds the maximum weight limit for universal railcar interchange. Table 6 summarizes available information on current and proposed cask shell materials and thicknesses.

Table 6

Shipping Cask Shell Materials and Thicknesses(Inches)

Shell Materials	**NSF-4**	**GA-4**	**GA-9**	**NAC-TSC**	**Lg MPC**	**Sm MPC**
Containment: Stainless Steel	1.73	2	2.13	4.1	5.25	4.38
Gamma Shield: Lead	6.6			3.7	0.5	0.5
Gamma Shield: Depleted Uranium		2.63	2.45		1.5	1.5
Neutron Shield: Borated Water	4.5					
Neutron Shield: Borated Polypropylene		4.5	3.5	5.5	6	4
Total Thickness	**12.86**	**9.13**	**8.08**	**13.3**	**13.25**	**10.38**

Source: Calculated from References 27 and 53

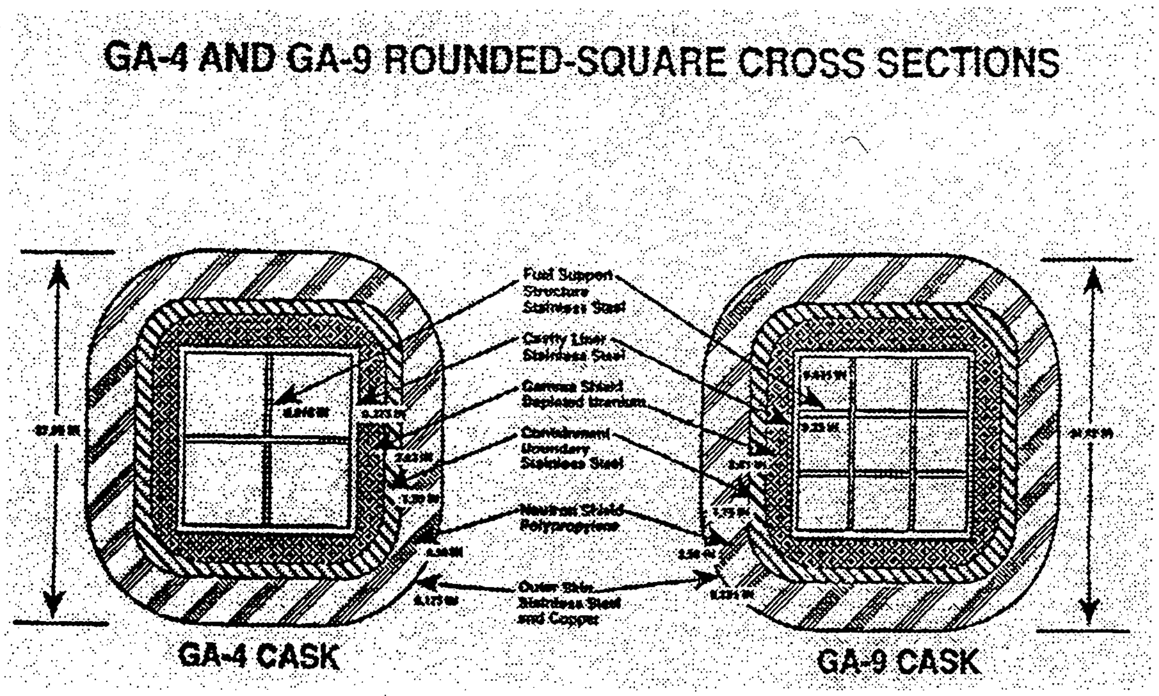


Figure 21. GA 4 and GA 9 Truck Casks (Cross-section)

Figure 21 shows a cross-section of the GA 4 and GA 9 casks. The side-to-side width of the GA 4 is 37 inches, while the GA 9 is 35 inches. The GA 4/9 designs differ from the casks assumed in the DOE and NRC consequence assessment in several respects: rounded square versus circular body, polypropylene neutron shielded versus steel shelled water jacket, and depleted uranium gamma shield versus lead gamma shield. These differences could result in greater vulnerability to attack with the reference weapon. The elimination of the water jacket could result in a larger release of respirable particulates.

Figure 22 shows a cross-section of the 125-ton MPC transportation cask. The side-to-side diameter of the 125-ton MPC transportation cask is 85 inches. The MPC transportation cask

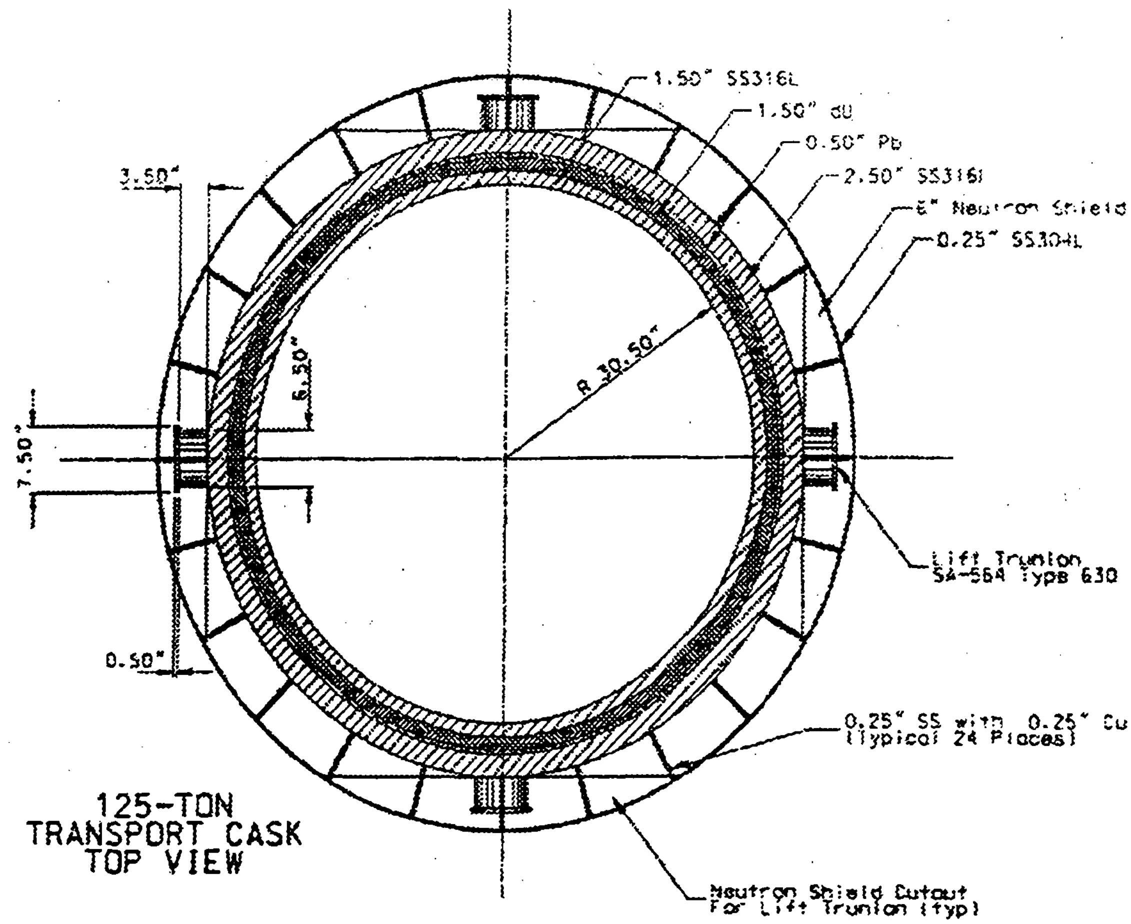


Figure 22. Large MPC Rail Transport Cask (Cross-section)

design differs from the casks assumed in the DOE and NRC consequence assessment in its polypropylene neutron shield (versus steel shelled water jacket) and its composite lead/depleted uranium gamma shield (versus solid lead gamma shield on the NFS-4 and solid depleted uranium gamma shield on the IF-300). There is insufficient information to determine whether or not these differences could result in greater vulnerability to attack with the reference weapon. The elimination of the water jacket could result in a larger release of respirable particulates.

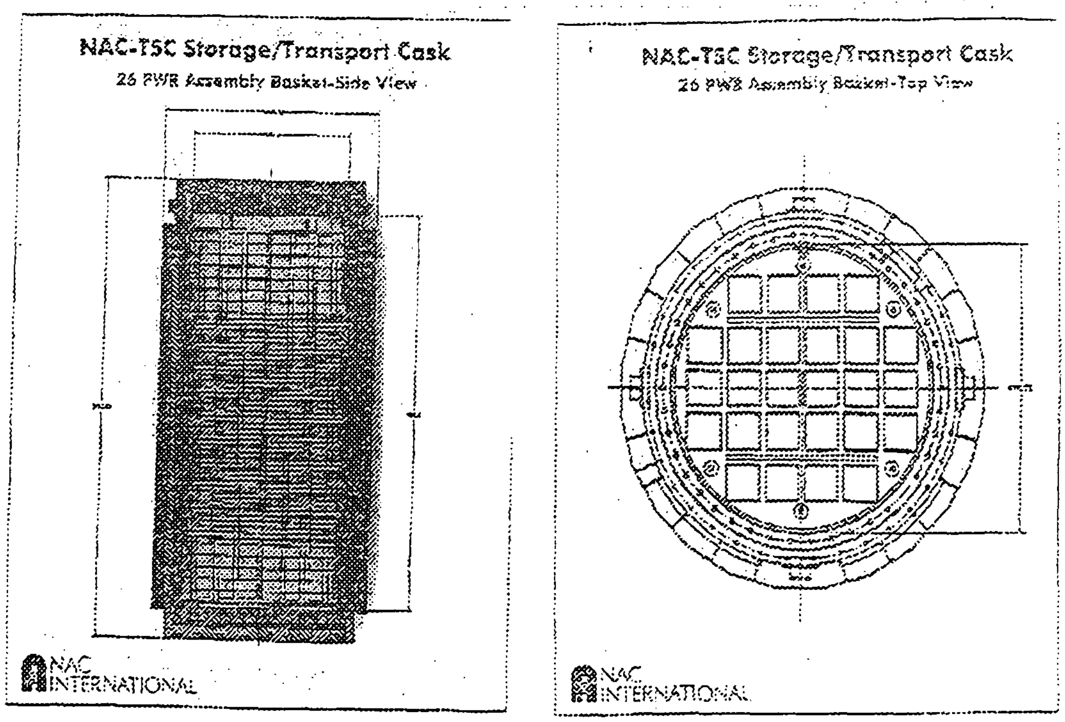


Figure 23. NAC-TSC Storage/Transport Cask

Figure 23 shows a cross-section of the NAC-TSC Storage/Transport cask. The side-to-side diameter of the NAC-TSC is about 96 inches. The NAC-TSC design differs from the casks assumed in the DOE and NRC consequence assessment in its polypropylene neutron shield (versus steel shelled water jacket). The NAC-TSC's solid lead gamma shield is comparable to, although thinner than, the solid lead gamma shield on the NFS-4. There is insufficient information to determine whether or not these differences could result in greater vulnerability to attack with the reference weapon. The elimination of the water jacket could result in a larger release of respirable particulates.

We recommend that the GA 4 cask be used as the reference truck shipment target and that the NAC-TSC be used as the reference rail shipment target for terrorism consequence assessment by NRC, DOE, and the State of Nevada. The GA 4 truck cask should be used because its design has nearly completed the NRC certification process and because it is designed to transport PWR SNF, the predominant type of SNF in the projected repository inventory. The NAC-TSC should be used because it has completed the NRC certification process and because it is also designed to transport PWR SNF.

Selection of Reference Spent Fuel Characteristics. The spent fuel shipped to a repository or centralized storage facility will have different radiological and physical characteristics and will be shipped in larger quantities per cask than was assumed in the DOE and NRC consequence assessments.

The reference spent fuel for repository shipments is a 10-year-old cooled PWR assembly. Under contract to DOE, Oak Ridge National Laboratories has characterized a wide variety of SNF and HLW types using the ORIGEN2 computer code. [Ref. 68] Table 7 summarizes the estimated inventory of major radionuclides and total radioactivity in one MTU of the reference spent fuel, in a truck cask with four reference assemblies, and a rail cask with twenty-one reference assemblies. [Note that the NAC-TSC rail cask contains 26 PWR assemblies, resulting in about a 24 percent greater source term.]

The spent fuel radionuclide inventory (calculated according to initial enrichment, burnup, and cooling time) and the quantity of spent fuel (weight and number of assemblies) per package determine the total amount of radioactivity (the source term) that could be released in a terrorist attack. The physical characteristics of the spent fuel and its response to blast impact and heat, particularly the fracture characteristics and the size distribution of particles, determine the amount of radioactive materials released from the cask and their dispersion, health and environmental impacts, and cleanup requirements.

We recommend that the reference spent fuel, as characterized by Oak Ridge National Laboratories using the ORIGEN2 computer code, be used for terrorism consequence assessment by NRC, DOE, and the State of Nevada.

Table 7

ESTIMATED INVENTORY, BY MAJOR RADIONUCLIDE, OF REFERENCE PWR SPENT FUEL

Nuclide	curies/ MTU	Percent of Total	curies/ TRUCK CASK	curies/ RAIL CASK
Kr 85	5,660	1.2	10,188	53,487
Sr 90	67700	14.39	121,860	639,765
Y 90	67700	14.4	121,860	639,765
Cs134	7420	1.58	13,356	70,119
Cs137	98200	20.89	176,760	927,990
Ba137m	93000	19.77	167,400	878,850
Pm147	9120	1.94	16,416	86,184
Eu154	5700	1.21	10,260	53,865
Pu241	95700	20.36	172,260	904,365
Cm244	2880	0.61	5,184	27,216
Other	171	3.65	30,895	162,200
Total	470,244	100	846,439	4,443,806

Source: Reference 68

The Reference PWR Assembly is a Westinghouse 17x17, 0.45 MTIHM, Initial Enrichment 3.72%, Burnup 40,000 Mwd/MTIHM, Decay Time 10 years

Selection of Credible Worst Case Attack Time, Location, and Weather Conditions. For purposes of the Yucca Mountain Environmental Impact Statement, a new and comprehensive terrorism consequence assessment must employ credible worst case assumptions about the timing and location of a potential attack and weather conditions during and after the attack, consistent with characteristics of the routes most likely to be used for shipments to a repository or storage site in Nevada.

Combinations of location, timing, and weather conditions are important determinants of impacts on public health and safety, environmental quality, and business activities and property values. These factors determine the number of people initially exposed to incident consequences, the nature and duration of exposure to incident consequences (especially exposure to released radionuclides), and the timing and effectiveness of emergency response activities.

The following examples are offered to illustrate the level of detail that should be expected in a comprehensive consequence assessment.

Urban location, attack on rail or truck cask. Given current routing assumptions, the consequence assessment should evaluate an attack at an urban location in metropolitan Clark County. The assessment should assume that the attack occurs during heavy evening commuter traffic congestion or during a nighttime special event. The assessment should assume worst-case weather conditions. High winds with no precipitation could cause rapid and widespread dispersal of radioactive particulates. Concentrated heavy rainfall could disperse radioactive materials through runoff and flash flooding. Credible severe weather scenarios for Clark County include a 12 hour period of sustained winds in excess of 30 miles per hour and 6 or more inches of rain during a 24 hour period. Immediate special concerns would be the evacuation of as many as several hundred thousand visitors and residents and the potential contamination of hotel, resort, and casino properties worth billions of dollars.

Rural location, attack on rail cask. Given current routing assumptions, the consequence assessment should evaluate an attack on a rail shipment at a rural location in southern Nevada between Las Vegas and the Utah-Nevada state line. The assessment should assume that the attack occurs at a time when emergency response would be slowed or delayed by other events or limited personnel, for example, during a weekend or on a major holiday. The assessment should assume worst-case weather conditions appropriate for the postulated attack location. If the attack occurred along a route segment subject to flash flooding, a credible severe weather scenario would be 6 or more inches of rain during 24 hours. Immediate special concerns, depending upon the postulated location of the attack, could include contamination of Indian reservation lands, private residences, agricultural lands, and Lake Mead (a major recreational resource and water supply source for Arizona, California, and Nevada). [Ref. 69]

RECOMMENDATIONS

Recommendations to the U.S. Nuclear Regulatory Commission

1. The NRC should completely reexamine the issue of terrorism and sabotage against spent nuclear fuel and high-level radioactive waste shipments in order to determine the adequacy of the current physical protection regulations under 10 CFR 73, and in order to assist the DOE and the affected stakeholders in the preparation of a legally sufficient environmental impact statement as part of the NRC licensing process for a geologic repository or an interim storage facility. The NRC should conduct a comprehensive assessment of the consequences of three types of attacks that have the potential for radiological sabotage: attacks against transportation infrastructure used by nuclear waste shipments; attacks involving capture of a nuclear waste shipment and use of high energy explosives against the cask; and direct attacks upon a nuclear waste shipping cask using anti-tank missiles. The consequence assessment should address the full range of impacts of a terrorism/sabotage event resulting in a release of radioactive materials: immediate and long term implications for public health; environmental impacts, broadly defined; standard socioeconomic impacts, including cleanup and disposal costs and opportunity costs to affected individuals and business; and so-called special socioeconomic impacts, including individual and collective psychological trauma and economic losses resulting from perceptions of risk and stigma effects.

2. As part of its comprehensive reexamination of terrorism/sabotage consequences, the NRC should engage an independent technical organization with appropriate expertise to advise the Commission on two critical issues: (a) the need for physical testing, full-scale and/or scale model, to evaluate weapons capabilities, cask vulnerability to attack with high-energy explosive devices, and the response of spent nuclear fuel to such attacks (specifically, to determine fuel mass release from a cask, particle size distribution of released fuel, and special concerns associated with volatile

radionuclides such as Cs-134 and Cs-137); and (b) the appropriateness of existing computer models for evaluating near-site environmental dispersion of released radionuclides, the resulting health effects, cleanup and disposal requirements, and economic costs.

3. The NRC should conduct its comprehensive reassessment of terrorism/sabotage consequences in a forum conducive to meaningful participation by all affected stakeholders. NRC should consider the creation of a stakeholder advisory group to assist the NRC in this task.

4. The NRC should publish a full report on all unclassified findings of its consequence reassessment, regardless of whether the Commission determines that modifications are necessary to the current physical protection regulations. The NRC should specifically avoid the approach followed in the 1984 proposed rulemaking, where stakeholders and the general public were never advised of the Commission's findings and conclusions.

5. The NRC should reevaluate the current definition of radiological sabotage used for determining the inclusion of events in the Safeguards Summary Event List. Current practice apparently results in the omission of at least some potential threats from this important risk assessment and risk management database.

Recommendations to the U.S. Department of Energy

1. DOE should address the issue of terrorism and sabotage against spent nuclear fuel and high-level radioactive waste shipments in the Yucca Mountain repository environmental impact statement (EIS), in any EIS prepared as part of the NRC licensing process for an interim storage facility, and in any separate EIS regarding construction of a new rail spur or other transportation infrastructure associated with a repository or storage facility. The State of Nevada and other stakeholders raised

these issues during the scoping process for the Yucca Mountain EIS in 1995. Since these issues have been previously presented to DOE, the Department should address these issues in detail in the draft EIS for Yucca Mountain. Specifically, DOE should evaluate the consequences of attacks against transportation infrastructure used by nuclear waste shipments, attacks involving capture of a nuclear waste shipment and use of high energy explosives against the cask, and direct attacks upon a nuclear waste shipping cask using anti-tank missiles. The draft EIS should address the full range of impacts of a terrorism/sabotage event resulting in a release of radioactive materials: immediate and long term implications for public health; environmental impacts, broadly defined; standard socioeconomic impacts, including cleanup and disposal costs and opportunity costs to affected individuals and businesses; and so-called special socioeconomic impacts, including individual and collective psychological trauma and economic losses resulting from perceptions of risk and stigma effects. The draft EIS should evaluate these impacts assuming worst case locations along probable transportation routes in Nevada. The draft EIS should also address impact mitigation and compensation strategies.

2. DOE should incorporate terrorism/sabotage risk management and countermeasures in all DOE transportation plans and contracts relating to the operation of a repository, interim storage facility, and/or intermodal transfer facility. In particular, DOE should address terrorism/sabotage risk management in any transportation service contracts awarded as a result of OCRWM's December, 1996, Draft Request For Proposals for Acquisition of Waste Acceptance and Transportation Services.

3. DOE should prepare a comprehensive report on the liability for costs and damages resulting from terrorism/sabotage attempts, successful or unsuccessful, against shipments to a repository, interim storage facility, or other DOE facility operated under authority of the Nuclear Waste Policy Amendments Act. DOE should specifically address the applicability of the Price Anderson liability system, including

limitations on liability for DOE transportation contractors and conditions necessary for NRC declaration of an Extraordinary Nuclear Occurrence; current requirements for transportation contractor coverage under private nuclear insurance pools; issues associated with negligence by shippers and carriers; and the applicability of state liability laws.

Recommendations to the State of Nevada

1. The State of Nevada should be prepared to participate in any NRC terrorism/sabotage consequence assessment and resulting proposal for rulemaking. The State of Nevada should continue to address terrorism/sabotage issues as part of its oversight of DOE site characterization activities, EIS preparation, and transportation planning.

2. The State of Nevada should, as part of its oversight of DOE activities, address transportation terrorism/sabotage issues specific to the State of Nevada, Nevada local governments, and Nevada Indian tribes. High priority issues include: (a) State, local, and tribal law enforcement agencies preparedness for terrorism/sabotage incidents; (b) rural impacts of terrorism/sabotage incidents, including impacts on farming, ranching, water supplies, and outmigration from small communities; and © impacts on Native American communities.

3. The State of Nevada should, as part of its oversight of DOE activities, continue to address larger transportation terrorism/sabotage issues such as the definition of domestic terrorist events, federal-state-local law enforcement responsibilities, comparative vulnerability of at-reactor storage versus shipment to and storage/disposal at centralized facilities, and consequences of attacks on infrastructure and shipping casks. Given the record of the past two decades, the State of Nevada should not assume that DOE and NRC will adequately address these issues.

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APPENDIX A

Congressional Record, Senate, July 31, 1996:

Excerpt from the U.S. Senate Debate on S.1936
The Nuclear Waste Policy Act of 1996

United States of America

Congressional Record

PROCEEDINGS AND DEBATES OF THE 104th CONGRESS, SECOND SESSION

Vol. 142 WASHINGTON, WEDNESDAY, JULY 31, 1996 No. 115

Senate

The Senate met at 9 a.m., and was called to order by the President pro tempore [Mr. THURMOND].

PRAYER

The Chaplain, Dr. Lloyd John Ogilvie, offered the following prayer:

Holy Lord God, we admit that we often try to live our lives within the narrow, limited dimensions of our own wisdom and strength. As a result, we order our lives around our own abilities and skills and miss the adventure of life You have prepared for us. We confess to You all the things we do not attempt; the courageous deeds we contemplate but are afraid we cannot do, the gracious thoughts we do not express; the forgiveness we feel, but do not communicate. Forgive us, Lord, for settling for a life which is a mere shadow of what You have prepared for us, forgetting that You are able to do in and through us what we could never do by ourselves.

Plant in us the vivid picture of what You are able to do with lives like ours, and give us the gift of new excitement about living life by Your triumphant power in the name of our Lord and Saviour. Amen.

RECOGNITION OF THE ACTING MAJORITY LEADER

The PRESIDENT pro tempore. The able Senator from Idaho is recognized.

SCHEDULE

Mr. CRAIG. Mr. President, this morning the Senate will immediately turn to the consideration of S. 1936, the Nuclear Waste Policy Act. The bill will be considered under a previous unanimous-consent agreement that limits the bill to eight first-degree amendments with 1 hour of debate equally divided on each. Following disposition of that bill, the Senate will resume consideration of the transportation appropriations bill which will also be considered under an agreement limiting first-degree amendments to that bill. Following disposition of those bills, the Senate may also be asked to turn to consideration of the VA-HUD appropriations bill. Therefore, Senators can expect a full legislative day with rollcall votes expected throughout the day and into the evening in order to complete action on the bills just mentioned or any other items cleared for action.

RESERVATION OF LEADER TIME

The PRESIDING OFFICER. Under the previous order, the leadership time is reserved.

NUCLEAR WASTE POLICY ACT OF 1996

The PRESIDING OFFICER (Mr. INHOFE). The Chair lays before the Senate S. 1936, which the clerk will report.

The assistant legislative clerk read as follows:

A bill (S. 1936) to amend the Nuclear Waste Policy Act of 1982.

The Senate resumed consideration of the bill.

AMENDMENT NO. 5055

Mr. MURKOWSKI. Mr. President, I call up amendment No. 5055 which is at the desk.

The PRESIDING OFFICER. The clerk will report the amendment.

The assistant legislative clerk read as follows:

The Senator from Alaska [Mr. MURKOWSKI] proposes an amendment numbered 5055.

Mr. MURKOWSKI. Mr. President, I ask unanimous consent that further reading of the amendment be dispensed with.

The PRESIDING OFFICER. Without objection, it is so ordered.

(The text of the amendment is printed in today's RECORD under "Amendments Submitted.")

Mr. MURKOWSKI. Mr. President, this amendment will solve a pressing environmental problem, a major environmental problem in our Nation, a problem that is looming as a liability to the taxpayers, and this will end an era of irresponsible delay.

This major environmental issue is simple to understand. That is, do we want 80 nuclear waste dumps in 41 States serving 110 commercial reactors and defense sites across the country—near our neighbors, our schools and populated cities? Or do we want just one in the remote, unpopulated Nevada desert where we tested and exploded nuclear weapons for decades?

Mr. President, I am going to yield some time on the amendment to the distinguished Senator from South Carolina, the Senate President pro tempore, Senator THURMOND, without losing my right to the floor.

Mr. THURMOND. I thank the able Senator from Alaska.

The PRESIDING OFFICER. The Senator from South Carolina.

Mr. THURMOND. Mr. President, I rise today in strong support of S. 1936, the Nuclear Waste Policy Act of 1996. In 1982, Congress passed the Nuclear Waste Policy Act, which directed the Department of Energy to develop a permanent repository for highly radioactive waste from nuclear powerplants and defense facilities. This act was amended in 1987 to limit DOE's repository development activities to a single site at Yucca Mountain, NV. Since 1983, electric consumers have been taxed almost $12 billion to finance the development of a permanent storage site. Despite DOE's obligation to take title to spent nuclear fuel in 1998, a permanent repository at Yucca Mountain will not be ready to accept this waste until the year 2010, at the earliest.

Mr. President, a July 16, 1996, Washington Post editorial states that the nuclear waste storage situation is not

• This "bullet" symbol identifies statements or insertions which are not spoken by a Member of the Senate on the floor.

The PRESIDING OFFICER. The Senator from Nevada [Mr. REID] is recognized.

Mr. REID. Mr. President, the Nuclear Waste Technical Review Board, in March 1996, recognized the problems with transportation. They recognized, as the senior Senator from Louisiana indicated, that there have been small loads of nuclear waste that traveled very short distances. But they go on to say—and that is the whole point, that they are in effect legislated out of business, because they said, "the Board sees no technical or safety reason to move spent fuel to a centralized storage facility."

Caliente of course means hot. It is not because it is hot weather. It is because they have hot water in the ground there. That is how this town got its name. The city of Caliente represents 0.05 percent of the people of the State of Nevada, 0.05 percent. They are desperate. We have 17 counties in Nevada. There is no county that is in more desperate economic condition.

Their mineral abilities are gone. Their agricultural interests are very sparse. A lot of land is owned by the Federal Government. And they have really struggled. Caliente was a railroad town. The railroad, in effect, has moved out on them. It does not stop there anymore. People who used to work for the railroads do not work there anymore. It is in deep, deep economic depression.

Senator BRYAN talked about one thing they wanted. They also wanted to start a cyanide plant there. They will take anything. I am sorry to say, they are so desperate for money.

Caliente represents, I think, a subject we want to talk about here. Caliente is remote. It is about 150 miles from Las Vegas. Nevada is, surprisingly, the most urban State in America. Mr. President, 90 percent of the people, approximately, live in urban areas, the Reno-Las Vegas areas. Only about 10 percent of the people live in rural Nevada, as we remember it. We have a lot of areas in Nevada that are lonely.

We have the loneliest road in America in Nevada. But Nevada is not the only place that has remote areas. Utah, eastern Utah is extremely remote. I have driven through parts of Colorado that are as remote as any place in Nevada ever was, as are parts of Arizona and New Mexico. The reason I mention that is we need to understand that not only is transportation a problem for the safety of carrying these canisters—and I say to my friend from Idaho, the 150 mile an hour—they may have run a test at 150 miles an hour, I do not know about that. But I do know the canisters have been certified by the Nuclear Regulatory Commission to this point for 30 miles an hour and for burning for 30 minutes. That is fact. So the 150 miles an hour, I do not know where that came from. They may have run some tests. But certification is for burning at 1,475 degrees for 30 minutes and speeds of 30 miles an hour.

We are concerned about unforeseeable accidents. We have pictures of train wrecks, Ledger, MT, Vernon, CA, Alabama. All over the country they have about 600 train wrecks a year. Most of them, thank Heavens, are not bad, but some are disastrous, like the one that burned for 4 days last year, like the one that closed the freeway between Las Vegas and Los Angeles for 4 days. So we have bad train wrecks.

I am not talking about what I am going to say in just a few minutes, because of what took place with TWA, and what took place in Atlanta with the bomb.

I talked about this 3 weeks ago prior to these horrible incidents. I want the RECORD to show I spoke earlier about these and other threats before these tragic event at the Olympics and TWA incident off the coast of New York.

No one wants to exploit the pain, the suffering, and the anguish of those people. Those of us who serve in the Congress, especially serve the western part of the United States, we seemingly live on airplanes. So, when these accidents happen, we all look inward.

But I must speak to the threat of terrorism, because the nationwide transport of spent nuclear fuel will provide targets of inconceivable attraction to terrorists, both foreign and, I am sorry to say, domestic; we have people who are terrorists within our own country, as indicated in the Oklahoma City bombing and probably in the Atlanta Olympic bombing.

We have enemies and they are not all outside the boundaries of this country. For whatever reason, though, these enemies detest parts of our country, and the foreign operations detest what our country stands for and its values. Our very freedoms are threatened. They dwell on hitting points of interest to the American public. That is why the White House is such a target. That is why this building is such a target. That is why we have a police force of almost 2,000 men and women who protect the people who work in these buildings and the tourists who come to this Capitol complex. That is why the Capitol Police have animals that sniff out explosives, animals that are around at all times looking at cars that come in and out, sniffing to find out if there are explosives. We have bomb detection units. We have bomb disassembly units. All over this Capitol complex there are plainclothes officers protecting the people who come into this building.

There are people who would do anything to cause terror to this country. So, Mr. President, we have to eliminate whatever we can that allows them targets.

There are many clandestine foreign interests. We know that. Some are led by leaders of countries. They want to publicize their existence and promote their goals through outrageous acts of blatant terror and destruction. What better stage could be set for any of these enemies of our country than a trainload or a truckload of the most hazardous substance known to man clearly and predictably moving through our free and open society?

You cannot move a 125-ton object or a train that is full of nuclear waste without having it marked and without notifying people it is coming through. These shipments, of necessity, must pass through our most populated centers, which provides opportunity for a successful attack for a terrorist to strike terror and public confidence in our form of Government.

Earlier today, I talked about something I received in the mail from St. Louis. It is a newspaper called Gateway to the Waste. It talks about how in St. Louis they are afraid of nuclear shipments there.

Each cask would contain a radiological equivalent of 200 Hiroshima bombs. All together the nuclear tonnage would be enough to kill everybody on Earth. These shipments would not only pass through populated centers but through remote and inaccessible territory. Remember, I say to my colleagues of the Senate, that the accident that occurred in Arizona occurred in a very remote area. A person went out there undetected and simply took some tools and took the track apart. When the train came over, the tracks spread and death and destruction was in its wake.

The opportunity to inflict widespread contamination to engender real health risk to millions of Americans is apparent. And people say, "Oh, no one would do that."

What happened in Japan? Sarin gas was collected and dispersed. They did not do a very good job. They only wound up killing dozens of people and causing respiratory problems and other forms of illness to hundreds and hundreds of people. That was a failure even though they caused death and destruction to that many people. If they had done it right, it would have killed thousands.

We must prepare for the realities accompanying a massive transportation campaign that would be required to consolidate nuclear waste at a repository site. We must deter our enemies through readiness and competent response before we undertake this dangerous program.

One of the things the Nuclear Waste Technical Review Board said is we are not ready for this. The Governors' Association hired some people to conduct a test to see how the State of Nevada— this was not done by the State of Nevada, but the Governors' Association did it to find out how Nevada is prepared—now remember, Nevada has dealt with things nuclear before with aboveground and underground nuclear testing—how we would deal with nuclear waste transportation through Nevada if something went wrong. We are not ready, not even close. If we are not ready, you can imagine how other States are. We must assure our citizens we only have to undertake this dangerous venture once. It is paramount we do it right the first time.

There is a growing danger in this country from both domestic and international terrorism. Exposure of this substance can lead to immediate sickness. It is much worse than sarin gas. Early death, and for less acute exposure, to years of anxiety and uncertainty as the exposed populations wait helplessly for the first onset of thyroid cancer, bone cancer, leukemia, liver and kidney cancer, and on and on.

We know that we must be prepared, and we are not prepared. The comprehensive assessment of its capacity to respond and manage a radiological incident in Nevada did not work out well. That is the way it is all over the country.

Mr. President, why are we concerned about terrorist incidents? We have weapons that are almost unbelievable. Most of us in this Chamber have gone shooting with a shotgun. We know how big a shotgun shell is.

Here we have a shell not even double the size of a shotgun shell, and this is a shaped charge warhead terrorist tool. It is 1½ inches in diameter and 4 inches long and, as described by scientists, it kind of works like a watermelon. When you squeeze the seed of a watermelon it squeezes the liner material and squirts out. This will pierce 5 inches of steel. That is what this chart shows.

Mr. President, if the Presiding Officer wanted to buy a weapon to spread terrorism around the United States, he could do it. It might take you a week, 2 weeks, but if you have money, you can buy from an arms dealer. I have pictured one weapon. We have lots of other weapons we can show, but this one weapon is a Russian version of a portable antitank weapon. This weapon is pretty accurate. At 330 yards, you can hit a target the size of my fingers here. It weighs 15 pounds. That is all it weighs. This weapon is a little more powerful than the one I just showed you, because this will fire 330 yards. It will go through 16 inches of steel.

The typical rail canister of nuclear waste is about 4 inches of steel plus some lead and some water. A piece of cake for this weapon that I just showed you.

But, Mr. President, weapons are all over, easy to pick up and purchase, weapons weighing 16 pounds, 22 pounds, penetrating up to 3 feet of steel.

You might say, no one could afford this. These weapons you can buy for $5,000, $10,000. That is all they cost. Buy a few shells with them. These are antiarmor weapons.

The reason, Mr. President, we should be concerned about this is that all nuclear waste is funneled into one small part of our country. It starts out this big with tens of thousands of shipments, but the more it goes, by the time it gets to Colorado, the circle is that big, and all through these parts of the country, Mr. President, you keep narrowing the scope. It is becoming easier and easier the farther west you go, the more remote it becomes, and the more concentrated volume of nuclear waste will be shipped there.

If I were a terrorist organization, this would be a piece of cake. These weapons will fire up to 300 to 400 yards. They are in very remote areas. You can go places in Nevada, Arizona, and Colorado where people do not go for days. Along those railroad tracks, you can be out there, camp, and all you are going to be interrupted by are the trains coming by. That is why they have been unable to catch the person in Arizona because he could have been gone for a day before the tracks separated, or longer.

So what are we going to do? I think what we should do is do what the Nuclear Waste Technical Review Board did and say, let us not subject the world and the country to the spread of this nuclear poison. We have not invested in the transportation planning. And the preparations are absolutely necessary for the safe transportation of this dangerous material through our heartland.

We have not addressed the spectrum of threats to safe transportation and not developed a transportation process that guards against these threats and are not ready to meet the emergencies that could develop because of a nuclear accident or a terrorist act. The Nuclear Waste Technical Review Board recognizes our lack of readiness. That is one of the reasons they argued against the transportation program proposed by this legislation. The lack of readiness, preparedness and careful planning is one of the main reasons I urge my colleagues to vote against this ill-conceived, unnecessary and premature approach to managing nuclear waste for our country.

Mr. President, we are talking about a substance that is the most poisonous substance known to man. We have been told by preeminent scientists, Dr. John E. Cantlon, Michigan State University; Dr. Clarence R. Allen, California Institute of Technology; John Arendt, of Arendt Associates; Dr. Gary Brewer, University of Michigan; Dr. Jared Cohon, Yale University; Dr. Edward Cording, University of Illinois, and on and on.

These people, 12 in number, are eminent scientists with no political agenda, scientists saying we are not ready to move this stuff. It is safe to leave it where it is. Leave it where it is. So we should leave it where it is.

This legislation is unnecessary. It is being pushed by the nuclear lobby. That is why it is being done, to save the nuclear industry money and pass the expense off to American taxpayers.

They are always in a rush—always in a rush. It took us many years before the permanent repository. We got it where science would control what went on. Lawsuits had to be filed. Legislation had to be passed. But that is not fast enough for them. Now they do not want to wait for science, which will come back and tell us in 1998 how the Yucca site is going to be. They are unwilling to wait for that because they want to save a buck.

They want to save a buck by passing the responsibility off to the Federal Government way ahead of time and, in the process, making this country vulnerable to accident by rail or car, and opening our country to more terrorist acts. The terror we have known in the past pales any time we think about what could happen if a terrorist was able to penetrate one of these nuclear shipments.

The PRESIDING OFFICER. Who yields time?

Mr. MURKOWSKI addressed the Chair.

The PRESIDING OFFICER. The Senator from Alaska is recognized.

Mr. MURKOWSKI. I thank the Chair.

I would like to comment about the remarks made by my good friend from Nevada relative to the concern we all have, the legitimate concern we have over terrorism. He makes the case that, you know, there is a terrorist threat and therefore we ought to leave it where it is.

Let us look at where it is, Mr. President. The chart behind me shows it is in 41 States. There are 81 sites out there. Is it logical to assume that we are better off to leave it there where it is exposed in 41 States at 81 sites or put it in one place—one place—out in the Nevada desert, where we have had over a period of some 50 years extensive nuclear tests, time and time again, an area where it is concentrated and can be supervised and guarded, namely, the one site in Nevada?

It just does not make sense if you are going to argue the merits of terrorism to have it all over the country, as I have indicated on this chart—41 States, 81 sites—or put it in one place where you can monitor, you can control it, you can guard it. You can take the necessary steps to ensure that the threat from terrorism is at a minimum.

I do not know an awful lot about ballistics, Mr. President, but I know something about a shotgun because I hunt ducks. I cannot comprehend a type of a shotgun that can go 300 yards and pierce through 5 inches of steel. What I do know is what the Department of Energy has supplied us with. They have done eight sabotage studies.

One of those included a 4,000-pound ammonium nitrate bomb that was similar in size, same makeup of what was used in the Oklahoma Federal building. They placed it in a container to see if they could pierce the cask. It was not breached, Mr. President.

Another test—unfortunately, they are not able to disclose this type of technology because it is a black program, but they stated that this device was 30 times larger than an antitank weapon. Although this weapon made a small hole in the container, there was no significant release of radioactivity. Make no mistake about it, if there is a puncture, it is not going to blow up.

The suggestion was made, you are going to have the equivalent of so many times of Hiroshima; if you are going to penetrate that cask, the radioactive material can come out. But it is very, very heavy. As a consequence, its tendency is to remain in the immediate area. But the point is, these casks are designed to withstand, if you will, the exposures associated with an accident, whether it be a railroad, whether it be a ship, or whether it be a highway.

I would like to turn a little bit to attitudes prevailing in Nevada. As I indicated earlier, we have some 268 signatures from Caliente. I have been able to obtain the completed Xerox of the one that I started on earlier, Mr. President, and was cut off. I think it is important to read what these people said, and that has been inserted in the RECORD.

We the undersigned, support recommendations for maximizing benefits and minimizing risks as outlined in the city of Caliente/Lincoln County Nevada joint resolution 1-95. As residents of the State of Nevada, the United States Constitution provides that, if the Nuclear Waste Policy Act is going to be amended to allow transportation of spent fuel rods through Lincoln County and the city of Caliente, we are entitled to provide input to any such proposals. Such input would request oversight of safety issues and receipt of benefits that may be associated to any transportation and/or storage facility located within Lincoln County.

That is the point of this amendment, Mr. President, to provide that assistance.

Mr. President, I ask unanimous consent that a letter from the International Association of Fire Chiefs, dated July 26, be printed in the RECORD.

There being no objection, the letter was ordered to be printed in the RECORD, as follows:

INTERNATIONAL ASSOCIATION OF FIRE CHIEFS,
Fairfax, VA, July 26, 1996.

Hon. FRANK H. MURKOWSKI,
Chairman, Energy and Natural Resources Committee, U.S. Senate, Washington, DC.

DEAR CHAIRMAN MURKOWSKI: The International Association of Fire Chiefs (IAFC) fully supports S. 1936 and urges its prompt passage.

Nuclear fuel has been accumulating and temporarily stockpiled since 1982 at numerous staging locations throughout the United States. The stockpiling of nuclear waste in so many removed locales renders them most vulnerable to potential sabotage and terrorist attacks. A plan to remove this nuclear fuel and coordinate its transport to a single secure designated interim storage facility at Yucca Flat, NV, in accordance with prudent planning, training, and preparation can be a safe, logical and acceptable alternative.

S. 1936 offers a plan to remove this spent fuel and coordinate its transport to a single secure interim storage facility. With proper planning, training and preparation, this spent fuel can be transported safely and efficiently over the nation's railways and highways.

We appreciate your leadership on this difficult but important issue.

Very truly yours,

ALAN CALDWELL,
Director, Government Relations.

Mr. MURKOWSKI. It states:

DEAR CHAIRMAN MURKOWSKI: The International Association of Fire Chiefs (IAFC) fully supports S. 1936 and urges its prompt passage.

Nuclear fuel has been accumulating and temporarily stockpiled since 1982 at numerous staging locations throughout the United States. The stockpiling of nuclear waste in so many removed locales renders them most vulnerable to potential sabotage and terrorist attacks.

That is what I said before. Do you want it over here in the 41 States in over 80 sites? The fire chiefs say, no, put it in one site.

A plan [they further say] to remove this nuclear fuel and coordinate its transport to a single secure designated interim storage facility at Yucca Flat, NV, in accordance with prudent planning, training, and preparation can be a safe, logical and acceptable alternative. Senate bill 1936 offers a plan to remove this spent fuel, coordinate its transport to a single secure interim storage facility. With proper planning, training and preparation, this spent fuel can be transported safely and efficiently over the Nation's railways and highways.

It is signed by Alan Caldwell, director, government relations, from the International Association of Fire Chiefs.

Here is a petition, Mr. President, to the President of the United States, signed by 600 workers associated with the Nevada test site. I previously entered the specific petition and narrative in the RECORD, but let me read what it says. This is signed by over 600 workers at the Nevada test site.

We who have signed this petition live in the State of Nevada. Many of us work at the Nevada Test Site. Some of us work on the Yucca Mountain project.

The [Nevada Test Site], an area larger than the State of Rhode Island, was chosen as a nuclear weapons testing site by President Truman. Its dry climate and remote location made it ideal for weapons testing 45 years ago. Those same factors make the NTS ideal for storing high level nuclear waste and spent nuclear fuel. There is now, in southern Nevada, a resident work force that is well trained and experienced in dealing with nuclear materials. We, who are part of that work force, believe the NTS presents a solution for the United States for the temporary and permanent storage of high level nuclear waste and spent nuclear fuel. It is a well secured site, it is remote, it has already been utilized for nuclear purposes, it has an experienced and well-trained work force and we as Nevada workers, want it.

We urge you to work with Congress to make the NTS the solution to this Nation's nuclear waste dilemma.

There you have it, Mr. President.

How much time is remaining?

The PRESIDING OFFICER. The Senator from Alaska has 17 minutes 8 seconds.

Mr. MURKOWSKI. I read the following letter from the Southern Nevada Building & Construction Trade Council, dated July 23, a letter to Senator CARL LEVIN.

DEAR SENATOR LEVIN: I am writing to thank you for your support of Senate Bill 1936 and I urge you to continue that support.

I am a representative of the many working men and women of Nevada who strongly support the passage of S. 1936.

Although we more often than not support the positions of Senator Harry Reid and Senator Richard Bryan, our views on this particular issue differ significantly from theirs. On behalf of my members I urge you to continue your support of S. 1936, as reflected by your recent vote in favor of cloture. We sincerely thank you for your position.

As way of introduction, I am President of the Southern Nevada Building and Construction Trades Council, Vice President of the Nevada AFL–CIO, and serve as an appointee of Nevada Governor Bob Miller to the Nevada Commission on Nuclear Projects. I have followed the nuclear waste issue in Nevada for many years. My years of experience at the Nevada Test Site goes back to a time when Nevada elected officials actually sought the opportunity to store high-level waste at the Test Site.

The 18,000 craftsmen that I represent, as well as over 100,000 members of the Nevada AFL–CIO, feel strongly that the Yucca Mountain Project is safe and can be good for Nevada. We recognize, perhaps better than most, the importance of health and safety in dealing with high-level waste and nuclear materials. We have dealt with it for many years and as the workers handling this material we have the most to lose if this program is not safely run. Based upon our past experience in Nevada, we have a great deal of confidence that this facility will be safe.

Nevadans are pragmatic people and I believe that, contrary to statements made by some Nevada officials, many if not most Nevadans would not contest the location of this facility in Nevada. Remember that we have tested over 900 nuclear devices in the Nevada desert with little local opposition. Like the nuclear weapons testing program the nuclear waste program is essentially a non-issue among rank and file Nevadans. We find it extremely difficult to imagine that you could possibly find a more willing political climate anywhere else in the United States for this type of facility.

We understand that you may have been asked, by members of the Nevada delegation, to oppose legislative efforts to move the nuclear material storage program forward. An immense amount of scientific study has been conducted at Yucca Mountain and it has conclusively found the location to be a superior one for this type of facility. Some officials from Nevada have made a concerted effort, using every conceivable means, to thwart this scientific and environmental program.

Enclosed you will find petitions signed by many Nevadans who support passage of this legislation. We intend to meet with the White House shortly to express our position and to transmit the petitions. Our message to the President will be: Move this program forward—do not allow partisan politics to stand in the way of a solution to this problem. Any other approach would be both bad politics and bad public policy.

As a fellow American, a fellow Democrat, and as a representative of the working men and women of Nevada, I urge your continued support of S. 1936.

It is signed by Frank Caine, president of the Southern Nevada Building Construction & Trade Council.

Mr. CONRAD. Will the Senator yield?

Mr. MURKOWSKI. I do not attempt to speak, obviously, for the people in Nevada. That is the job of the Senators from Nevada. I do think it represents a significant voice to be heard and to be brought to the floor.

I yield on the Senator's time.

The PRESIDING OFFICER. The Senator from North Dakota has no time.

Mr. MURKOWSKI. I yield very briefly for a question if it is on my time because we are running short.

Mr. CONRAD. I have been increasingly concerned about the notion of the terrorist threat, and I am very interested in the answer of the Senator from Alaska.

It strikes this Senator, when you are talking about 100 different locations in the shipment of nuclear fuel from around the country to a single spot, that the risk of a terrorist threat increases dramatically; I just ask the Senator from Alaska, in talking to security people—in fact, I talked to Secret Service people about when the President is most vulnerable, and they told me they believe the President or anybody that they are guarding is most vulnerable when they are in transit. In fact, they feel they are most vulnerable when they are getting in or out of the vehicle.

I was thinking how that relates to the circumstances we face here. We saw that with President Reagan and the assassination attempt when he was getting into a vehicle. Rabin was assassinated when he was getting into a limousine, because you know where a person is, you know where they will be, that is when they are most vulnerable.

It strikes me that the same thing may be the case with respect to the transporting of these materials, and I am interested in the reaction of the Senator from Alaska to that.

Mr. MURKOWSKI. If I may respond to the Senator from North Dakota, that is the very point we are talking about. Terrorism is a threat, but we have this currently in 41 States at 81 sites, and the ability to secure those sites from terrorism in its current form is much more difficult than having it in one central spot, because that is where it will be permanently stored, either until Yucca Mountain has a permanent repository or, during the interim, until the permanent repository is set.

What we are looking at here is one site, one storage capability, one set of experienced personnel to guard against terrorist activity, as opposed to the chart, which I will again leave for the Senator to view, 41 States and 81 sites.

It just simply makes sense. The Senator from North Dakota was not here when I entered into the RECORD a letter from the International Association of Fire Chiefs which simply says:

. . . so many removed locales renders them most vulnerable to potential sabotage and terrorists attacks. A plan to remove this nuclear fuel and coordinate its transport to a single secure designated interim storage facility at Yucca Flat, NV, in accordance with prudent planning, training, and preparation can be a safe, logical and acceptable alternative.

So this is the very concern we are talking about. Obviously, you are not going to store in these sites forever. That is a given. You have to take it out of these sites at some point in time. The Federal Government has collected almost $12 billion from the ratepayers. It has entered into a contractual agreement. We are talking about reneging on the agreement, basically, if we don't go ahead with it, and leaving it where it is for an undetermined period of time until then you decide to move it. It is inevitable that you are going to move it. We are talking about here—once you move it, the threat of terrorist activities associated with it are much reduced because you don't have that number of sites in that exposure in the 41 States.

So the logic, I think, speaks for itself. I think, from the standpoint of terrorism, exposure is less dramatic if you have it at one site where it is easier to secure.

I think my time has about expired.

The PRESIDING OFFICER (Ms. SNOWE). The Senator has 8 minutes remaining.

Mr. CONRAD. Might I ask my colleague to yield me some time so I might pursue this?

Mr. BRYAN. How much time does my friend require?

Mr. CONRAD. A couple of minutes.

Mr. MURKOWSKI. How much time remains on the other side?

The PRESIDING OFFICER. There are 9 minutes 50 seconds remaining.

Mr. BRYAN. I yield 3 minutes to the Senator from North Dakota.

Mr. CONRAD. Madam President, I can understand, with respect to a terrorist threat, that if you had it at one site, it is easier to guard and secure than at 81 sites. What really raises questions, at least in my mind, is when this material is in transit, because now you are not talking about 81 sites, you are talking about an infinite number of places where you are vulnerable to some kind of terrorist threat. So, to me, it is not a question of 81 sites versus 1 site, it is a question of being in transit from 81 sites to 1 known place. If I were trying to put myself in the position of a terrorist, and I knew that all this material has to go through a series of locations to arrive at one destination, that makes it very vulnerable to a terrorist attack. So the question I really have is, aren't you most vulnerable when this material is in transit?

Mr. MURKOWSKI. I respond by asking my friend from North Dakota, is it not inevitable that at some point in time, in order to meet the contractual commitment, you are going to have to move this anyway?

Mr. CONRAD. Yes.

Mr. MURKOWSKI. So it is still going to be vulnerable to terrorist attacks.

Mr. CONRAD. I think, without question, my own view is that, obviously this material is going to have to be moved at some point. But, on the other hand, perhaps the technology will be developed that would allow you to deal with this material at those locations and not have to be transporting it to a single site in one place in the country where you are vulnerable. It would seem that it would be easy for a terrorist to look at the map and say, "Here are the sites it is coming from, and here is the one place on the map it is going to." You could draw a series of sequential rings and, with a high degree of confidence, know this material is going to pass through there, and you are, in that way, highly vulnerable to a terrorist threat.

Mr. MURKOWSKI. Madam President, the Senator from——

Mr. BRYAN. On whose time is the Senator from Alaska responding?

Mr. MURKOWSKI. On my own time. First of all, the Senator from North Dakota is suggesting that we dispose of it on-site somehow through advanced technology. That suggests reprocessing, which we don't allow. So that is basically a nonalternative. Some people suggest that is somewhat unfortunate because, in France, they do reprocess, reinject. They don't bury the plutonium like we do. They put it back in the reactors and burn it.

Now, the inevitability of the question of whether or not you leave it where it is and subject yourself to the potential terrorist exposure in 41 States and 81 sites—that suggests that you are not going to have the same degree of security and experience in all these sites because you cannot possibly cover that many sites. So you put it at the one site in Nevada where you can provide the security. So the terrorism exposure in Nevada is, for all practical purposes, eliminated. Your exposure is shipping them, granted. That is why the casks are designed as they are designed.

As I said in an earlier statement, the Army has tested a device 30 times larger than an antitank weapon, and although it made a small hole in the cask, there was no release of radioactivity. So you can't eliminate the entire risk, but you can eliminate, to a large degree, the technical design—this is a heavy thing; the terrorists are not going to run off with it. They have to do something very significant. Obviously, there is going to be security associated with the movement. I think we are talking about 10,000 casks. I defer to the Senator from Louisiana who, I think, wants to address the Senate.

Mr. JOHNSTON. Madam President, I appreciate my colleague yielding to me. They have done studies on these shippings, and what they have found is that upward of 10,000 to 20,000 shipments have already been made. They say numerous analyses have been performed in recent years concerning transportation risks associated with shipping spent fuel. The results of these analyses all show very little risk under both normal and accident conditions. The safety record has been very good in corroboration of the low-risk estimate analytically. In fact, during the decades that spent fuel has been shipped, no accident has caused a radioactive release. What they have done is they have made models both on the computer and they have done actual tests. For example, there was a chart up there that showed that they hit a cask at 80 miles an hour with a train, and they dropped them from buildings and all that. In none of these was there a risk.

I might add that we ship nuclear warheads all the time. We don't ship those actually in these kind of casks. Frankly, I don't know how they ship them, but they are not sealed off as these casks are. They have gone to the extent—in one instance, they said a shipping cask has been subjected to attack by explosives to evaluate the cask and spent fuel response to a device 30 times larger than an antitank weapon. They attacked one of these with a weapon 30 times larger than an antitank weapon. The device would carve approximately a 3-inch diameter hole through the cask wall that contained spent fuel, and it was estimated to cause a release of about one-third of an ounce. "No transportation"—this is a quote—"can be identified that would impose anywhere near the energy per unit volume caused by this explosive attack."

So even if you get a weapon 30 times larger than an antitank weapon and attack the cask with it, all it does is have a release of about one-third of an ounce. So I submit to my colleague that, I guess you can postulate some accident where some meteorite might come down and happen to hit a railroad train in just the right way and somehow that could harm somebody. But they have postulated about every conceivable risk, including a weapon 30 times larger than an antitank weapon, and they postulate only one-third of an ounce of release—that, plus the fact that there has never been a release of radioactivity in 4 decades of these transportations, from 10,000 to 20,000 shipments in this country alone, not to mention those around the world.

I would say there are things to worry about. But I honestly do not believe that transportation is one of them.

Mr. CONRAD. Let me ask my colleague.

Mr. REID. Madam President, I would be happy to yield to my friend, but I want to respond directly to the statements made by the Senator from Louisiana.

This is pure doubletalk. The fact of the matter is that the weapon that they used to test was a device designed to destroy reinforced concrete pillars and piers. The weapon was not designed to destroy a structure like a nuclear waste canister. In fact, the weapon used for testing performed its military mission so poorly that our military forces abandoned this device for a better design. The weapon used, even though it was not much good, did perforate the canister. The hole is small, and there was leakage, but it was not a great deal of leakage.

But everyone looking at this knows that the weapon that has been used—any of the weapons that I have on this chart are manufactured all over the world—would perforate this thing like that—16 inches of steel, 36 inches of steel, 28 inches of steel.

This is, in all due respect to the Senator from Louisiana, who is a tremendous advocate for the nuclear industry, part of their doubletalk. They have not been willing to test these canisters the way they should be tested, and the Nuclear Regulatory Commission has said to this point that all they have to do is to be able to withstand a maximum of 30 miles an hour and a fire for 30 minutes. That is totally inadequate not only for accidents, but for terrorist activities.

I yield now to my friend from North Dakota.

Mr. CONRAD. Madam President, I thank my friend from Nevada.

I just go back to this question. It does strike me, given the rise of terrorist activity not only in this country but around the world, that when you put in motion from 80 different sites around the country, from 41 States, thousands of these casks headed for one location, that if you were a terrorist organization—it would take very little calculation to figure out where this is most vulnerable—you would have the potential here for a terrorist organization when this stuff is most vulnerable, when it is in motion, when it is in transit, to attack either a train or a truck and get possession of this material and thereby be able to threaten dozens of cities in America.

I must say, when I have talked to security people—again, I talked to a person who was in the Secret Service—with respect to when they think something that they are guarding is most vulnerable, they said without question it is when it is in transit, when it is on the move. That is when it is the most vulnerable.

Mr. JOHNSTON. Madam President, will the Senator yield?

Mr. CONRAD. Yes.

Mr. JOHNSTON. Is the Senator suggesting that we leave it permanently at the 70-plus sites around the country?

Mr. CONRAD. No. This Senator is suggesting that maybe we ought to revisit the question of reprocessing in this country. That is an alternative. Maybe we ought to consider various other technological alternatives that may present themselves. I am just raising the question. With what is going on in terms of terrorist threats abroad and in this country, are we doing a wise thing by setting up a circumstance in which this material starts to move from 80 sites around the country to one defined location in America? That troubles me.

I really am struggling myself with the question of how to respond to that. I must say it has made me rethink the whole question of reprocessing. I wonder sometimes if we have made wise choices in this country.

Mr. JOHNSTON. If I may answer that, because the Senator is a very thoughtful Senator and it is a fair question.

First of all, let me say, on the issue of reprocessing, you would need a central facility for reprocessing anyway. So that does not solve the transportation problem.

Second, I would say to my friend that the studies that have been done—and you have four decades of experience with transportation of this fuel with never a radioactive release, plus you have a lot of postulated accidents. For example, they have taken actual accidents and made the studies of what that would have done to nuclear waste had it been involved. In one, in April 1982, there was a three-vehicle collision involving a gasoline truck trailer, a bus, and an automobile which occurred in a tunnel in which 88,000 gallons of gasoline caught fire and burned for 2 hours and 42 minutes. For 40 minutes the fire was at 1,900 degrees Fahrenheit. If a nuclear waste canister had been involved in this accident, it would have suffered no significant impact damage, and the fire would not have breached the canister. There would have been no radiological hazard. The spent fuel in the canister would not have reached temperatures high enough to cause fuel cladding to fail.

We go on here to other postulated accidents. A train containing both vinyl chloride and petroleum—the tanker cars derailed and caught fire. The fire burned for several days and moved over a large area. There were two explosions. Had nuclear waste canisters been on the train, they would not have sustained any damage from the explosion. They might have been exposed to the petroleum fire for a period ranging from 82 hours to 4 days. Even so, the canisters themselves would not have been breached.

Mr. CONRAD. Will the Senator yield?

Mr. BRYAN. Madam President, we have just a little time left.

Mr. CONRAD. I would like to conclude with this question.

My understanding is that those are accident scenarios. What concerns this Senator is a terrorist scenario when terrorists launch an attack on these materials when they are in transit and most vulnerable. I must say that I think it is something that we have to be concerned about.

Mr. JOHNSTON. The point is this, though: They have tested it with weapons 30 times bigger than antitank weapons with direct hits. That caused a breach. Only a third of an ounce comes out. There are many, many much more lucrative targets, by orders of magnitude more lucrative for terrorists, everything from chemicals that travel throughout the country every day, from LP gas to others which are many, many times easier to breach and would cause a much bigger problem. The essential thing is that nuclear waste is not a volatile matter.

Mr. BRYAN. Madam President, I say to my colleague that this is on my time.

How much time is left?

The PRESIDING OFFICER. Approximately 2 minutes.

Mr. BRYAN. If the Senator uses his own time, I have no problem with it. But I am not prepared to yield any more time.

Mr. JOHNSTON. I would be finished in just a moment.

Mr. MURKOWSKI. Madam President, I ask unanimous consent that the other side have 2 more minutes total and that we may have 1 minute on this side.

The PRESIDING OFFICER. Is there objection?

Without objection, it is so ordered.

Mr. JOHNSTON. Madam President, nuclear waste traveling the country is, first of all, solid in form. It is sealed in a cask that, as I say, if you get a direct hit by something 30 times more powerful than an antitank weapon, what do you get? You get a third of an ounce of release. What does that do? It does not explode. It is not gaseous. It does not get down to the water supply. It is, as these matters go, relatively benign. And, even so, you cannot imagine a situation other than a terrorist attack where there is any release at all.

So I submit that there are a lot of things to worry about, but transportation is not one of them.

Mr. MURKOWSKI. If I may, Madam President, take the last 30 seconds in response to the Senator from North Dakota, we have seen in Europe the movement of over 30,000 tons of high-level nuclear waste in countries that are exposed to terrorism at a far greater theoretical sense than the United States. There has never been one instance of a terrorist activity associated with movement by rail, highway, or ship. Terrorists are not going to necessarily look at terrorizing a shipment when they can move into nerve gas and weapons disposals that are moving across this country—all types of material that are associated with weapons —where they can create an incident of tremendous annihilation on a population.

This is very difficult because it is secure, in a cask; it is guarded; and it has been proven it has moved through other countries, particularly Great Britain, France, in Scandinavia, and to some extent starting in Japan. So there is a risk associated with everything. But we have not had terrorist activity in this area because there are other more suitable sites.

The PRESIDING OFFICER. The Senator's time has expired.

Mr. BRYAN addressed the Chair.

The PRESIDING OFFICER. The Senator from Nevada.

Mr. BRYAN. I thank the Chair.

Mr. President, I appreciate the statement of the senior Senator from North Dakota, his expression of concern about the vulnerability that we have to terrorism. It is a fact of life in 20th century America. All of us apprehend, lament, and regret it, but it is a very real fact. I must say, just as the bad guys in the Old West always knew where the stagecoach was most vulnerable—it was not when it was at the office; it was not when it was being unloaded at the bank—it was out on the road, so too when we are talking about thousands and thousands of miles of rail and highway shipments. There are so many places that a terrorist could find a point of vulnerability. The concerns that my colleague from North Dakota mentioned I believe are very real and very genuine, so I thank him very much for his explanation.

Let me just make one other point here. It is something we constantly hear about, that this bill will result automatically in not 109 sites but 1 site. Mr. President, that is just absolutely false, absolutely false. Each of the nuclear reactors that are currently generating power have spent fuel rods contained in the pools. They remain there at least for 5 years. If we assume that every reactor in the country is going to close, which is certainly not the predicate of the Nuclear Regulatory Commission, under the current existing licenses some nuclear utilities would remain open at least until the year 2033. So all this bill would do in terms of concentrating storage would add not 109 but you would have 110 sites, namely the new facility that they have proposed to construct at the Nevada test site for interim storage.

So this ad, I know, the nuclear utilities love. They spend millions of dollars in advertisements in magazines and publications that give one the impression, wow, if we just opened up this facility at the Nevada test site there will not be nuclear waste stored any place in the country.

That is wrong.

May I inquire as to how much more time the Senator from Nevada has?

The PRESIDING OFFICER (Mr. HELMS). All time has expired.

Mr. MURKOWSKI addressed the Chair.

The PRESIDING OFFICER. The Senator from Alaska.

Mr. MURKOWSKI. Mr. President, I ask for a voice vote on the amendment.

The PRESIDING OFFICER. The question occurs on agreeing to amendment No. 5048 offered by the Senator from Alaska.

The amendment (No. 5048) was agreed to.

Mr. MURKOWSKI. Mr. President, I move to reconsider the vote.

Mr. JOHNSTON. I move to lay that motion on the table.

The motion to lay on the table was agreed to.

The PRESIDING OFFICER. Are there further amendments to the bill?

Mr. REID. Mr. President, if I could just confer for a few minutes with my friend from Alaska and inform the rest of the Senate, what we are trying to work out now—and we do not know we can do it, but we are trying to—on this side we have three amendments. We want to vote on one of those amendments, a recorded vote. We would like that, if it is OK—we have a Democratic conference that is starting at 4. We would like to do that at 3:30 and then have final passage at approximately 5 o'clock and dispose of the other amendments in the interim by voice vote.

I have spoken to the Senator from Alaska. I know he has to confer with others to see if that can be worked out. Otherwise, we can do something else. In the meantime, we will go ahead and offer an amendment.

Mr. MURKOWSKI. Mr. President, I conferred with the Senator from Nevada and my colleague, Senator JOHNSTON, and I want to check with our leadership.

It is my understanding the next amendment will be offered by the Senators from Nevada, and they would want a rollcall vote on that amendment?

Mr. REID. No, the next amendment, we will offer and talk about it a little bit and have a voice vote.

Mr. MURKOWSKI. Voice vote. The one after that you would like—

Mr. REID. The one after that we would—

Mr. MURKOWSKI. Might I ask whether the Senators intend to use their full 30 minutes?

Mr. REID. We would be willing to work out something after this so the time is equally balanced.

Mr. MURKOWSKI. I will entertain then the amendment that is about to be offered that would require simply a voice vote, and that will give me an opportunity to check with the leadership on this side and then respond to the Senators concerning their proposal.

I thank the Chair and yield to my colleague from Nevada.

The PRESIDING OFFICER. The Senator is recognized.

Mr. BRYAN. I thank the Chair.

AMENDMENT NO. 5075

(Purpose: To specify contractual obligations between DOE and waste generators)

Mr. BRYAN. I send an amendment numbered 5075 to the desk and ask for its immediate consideration.

The PRESIDING OFFICER. The clerk will report.

Mr. MURKOWSKI. If I may interrupt, I assume there is acknowledgement that the Senators contemplate a voice vote prevailing on our side?

Mr. BRYAN. That is correct. We are not requesting that a rollcall vote occur with respect to amendment 5075.

Mr. MURKOWSKI. The voice vote that the Senators are proposing, they are assuming we would prevail?

Mr. REID. I would say to my friend from Alaska, he has not heard the argument yet. He may be persuaded.

Mr. MURKOWSKI. I will take my chances.

The PRESIDING OFFICER. The clerk will report.

APPENDIX B

U.S. Nuclear Regulatory Commission Notice of Proposed Modification of Protection Requirements for Spent Fuel Shipments

NUCLEAR REGULATORY COMMISSION

10 CFR Part 73

Modification of Protection Requirements for Spent Fuel Shipments

AGENCY: Nuclear Regulatory Commission.

ACTION: Proposed rule.

SUMMARY: The Nuclear Regulatory Commission is considering amending its regulations for the physical protection of irradiated reactor fuel in transit. The issue under consideration is one of safeguards rather than safety. The amendments would take into account new data from a research program and from other sources that indicate that the consequences of successful sabotage of an irradiated fuel shipment in a heavily populated area would be small compared to the consequence estimates that prompted issuance of the current rule. For certain spent fuel shipments, these amendments would provide continued protection against sabotage while at the same time relieving the licensee of non-essential requirements.

DATE: Comment period expires September 10, 1984.

ADDRESSES: Written comments should be submitted to the Secretary of the Commission, U.S. Nuclear Regulatory Commission, Washington, DC 20555, Attention: Docketing and Service Branch. Copies of comments on the proposed rule may be examined and copied for a fee at the NRC Public Document Room, 1717 H Street NW., Washington, DC.

FOR FURTHER INFORMATION CONTACT: Carl B. Sawyer, Office of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commision, Washington, DC 20555, Telephone: 301-427-4186.

SUPPLEMENTARY INFORMATION:

Background

The NRC carries out a continuing series of studies to aid in determining the measures that are needed to protect radioactive material, including irradiated (spent) fuel, against sabotage. During the mid-1970s, studies (NUREG-0194, "Calculations of Radiological Consequences from Sabotage of Shipping Casks for Spent Fuel and High-Level Waste," February 1977; and NUREG-0170, "Final Environmental Statement on the Transportation of Radioactive Material by Air and Other Modes," December 1977), estimated the health effects of a radiological release in a non-urban area resulting from a high-explosive assault of a spent fuel cask. The estimated risks were not considered to be substantive enough to warrant regulatory action. A subsequent study by Sandia Laboratories included a chapter on the sabotage of spent fuel in urban areas of high population density (SAND 77-1927, "Transport of Radionuclides in Urban Environs: A Working Draft Assessment"). This study suggested that the sabotage of spent fuel shipments had the potential for producing serious radiological consequences in areas of high population density. The Commission concluded that, in order to protect health and minimize danger to life and property (sections 161b and 161i(3) of the Atomic Energy Act of 1954, as amended), it was prudent and desirable to require certain interim safeguards measures for spent fuel shipments. The focus of concern was on possible successful acts of sabotage in densely populated urban areas. Because of the possibility that spent fuel shipments could be hijacked and moved from low population areas to high population areas, the interim requirements applied to all shipments, even though the planned shipment route did not pass through a densely populated urban area. The interim requirements were to be in effect until the results of confirmatory research became available and were analyzed.

The interim rule, which set forth physical protection requirements in 10 CFR 73.37, was issued on June 15, 1979, and was made effective on July 3, 1979. The rule was issued without benefit of public comment, but at the time of publication public comment was invited. Afte reviewing the public comments and after taking into account its experience in administering the rule, the NRC, on June 3, 1980, published amendments to the rule. The amendments were made effective on July 3, 1980, and the amended rule is currently in effect as 10 CFR 73.37(a) through (e).

Related Research

SAND 77-1927, which prompted issuance of the protection requirements, contained estimates which were unavoidably subject to large uncertainties due to a lack of technical data. A later draft of the Sandia report ("Transportation of Radionuclides in Urban Environs: Draft Environmental Assessment") was published by the NRC as NUREG/CR-0743. Although this draft predicted less serious consequences, a significant degree of uncertainty still remained that could be resolved only by further study and experiments.

Investigators at that time agreed and continue to agree (1) that consequences of an act of sabotage would be a direct function of the quantity of spent fuel that would be released in respirable form, and (2) that the only credible means of malevolent generation of respirable particles would be through the use of a large quantity (tens to hundreds of pounds) of high explosive skillfully applied. Little information was available to aid in predicting the response of spent fuel and spent fuel casks to explosive sabotage.

The NRC and the Department of Energy (DOE) responded to this need for technical data by sponsoring separate but coordinated experimental programs. Both programs were designed to yield information about the release from a specified reference sabotage event, which was defined as follows. Saboteur skills were specified as those of an experienced military or commercial explosive demolition specialist. Familiarity with a wide range of kinds and configurations of explosives was assumed. Use of up to hundreds of pounds of military or commecial explosives was permitted. For the special case of shaped charges, use of the U.S. Army M3A1 was assumed. It is the largest shaped charge readily available. An M3A1 causes damage through formatin of a high pressure particulate jet which may be a fraction of an inch in diamter and has the capability to penetrate two or more feet of metal, eroding everything in its path. From the outset, it was expected that a shaped charge would be more efficient than other configurations in producing respirable particles. For that reason the M3A1 was designated as the reference explosive. The refernece cask was specified as a single-assembly cask. The specificaton is conservative since a single-assembly cask has smaller dimensions than a multiassembly cask and is, therefore, more likely to yield a greater quantity of respirable particles (per assembly) in response to a given level of explosive sabotage.

A series of experiments using model (small-scale) explosives against simulated casks containing irradiated fuel characterized the NRC-sponsored program. These experiments used pressurized water reactor (PWR) fuel with a burnup of approximately 30,000 megawatt days per metric ton of heavy metal and approximately six-and-a-half-year cooling. Measurement of the quantity of released material revealed the fraction that was made up of particles of respirable size (those having a diameter of less than four microns). Upward scaling permitted the data to take into account the effect of the reference explosive and a full-scale cask. Scaling led to the conclusion that less than nine grams of spent fuel would be released in respirable form if the reference charge were used successfully against a cask containing a single PWR spent fuel assembly. Using results of the METRAN computer code for health conseuences (one of two health consequence codes used in SAND 77-1927 and NUREG/CR-0743) as set forth in Table 5-6 of NUREG/CR-0743 and assuming 150-day rather than six-and-a-half-year cooling, reseranchers found that the average radiological consequence of a release in a heavily populated area such as New York City would be no early fatalities and less than one (0.4) latent cancer fatality. Early fatalities are those that occur within one year after exposure to the radioactive material. Latent cancer fatalities are those that occur at any time following the exposure and could result from the intitial exposure or from any long-term exposure to low levels of contamination.

The average consequence values just cited were selected as being the most representative of the values that were calculated for the specified release. Either higher or lower consequence values can be obtained, depending on the circumstances that are assigned. The following is an example from among the higher values that can be obtained from the data. For the most densely populated area studied (up to 200,000 persons per square mile), at evening rush hour on a business day, and in the most unfavorable location for a release, the calculated radiological consequence (peak consequence) based on data from Table 5-4 of NUREG/CR-0743 is no early fatalities and less than three (2.9) latent cancer fatalities.

The results of an explosive sabotage experiment vary from experiment to experiment, and only a limited number of experiments can be performed. The results of the NRC-sponsored program are based on four scaled experiements using irradiated fuel, and the largest measured release value was used to derive the nine-gram value cited. In addition, a number of supporting tests were performed to establish shaped charge jet characteristics and jet-to-fuel-pin interaction.

Results of the NRC-sponsored research program (as well as those of the DOE program to be discussed subsequently) assume sabotage of a single-assembly cask, while the original SAND 77-1927 and NUREG/CR-0743 estimates assume a three-assembly cask. For the levels of release under consideration here, the releases and the health consequences for a three-assembly cask are calculated to be, at worst, double those for a single-assembly cask. The presence of additional assemblies in a cask would increase the likely release, but only in proportion to the number of assemblies that lie in the roughly straight line path of the jet. For more than three PWR assemblies (a fully loaded rail cask could contain 10 PWR assemblies) the upper bound of release would likely increase roughly in proportion to the square root of the total number of assemblies contained in a cask. On the basis of energy release from the explosive, it is expected that the number of fatalities from a sabotage explosion would be greater than the number of radiologically induced fatalities.

Explosive charges other than shaped charges were considered. In other experiments, scaled charges representing full-scale charges of up to several hundred pounds of explosive did not breach the cask's inner containment components. Accordingly, such full-scale charges appear unlikely to produce any release of spent fuel and hence unlikely to cause radiological consequences.

The program sponsored by DOE included one full-scale and several small-scale experiments. The full-scale experiments used a reference charge against a full-scale cask containing a single unirradiated surrogate fuel assembly. Again the quantity of material released from the cask was measured, and the released quantity was analyzed to determine what fraction was composed of respirable-sized particles. About three grams of respirable surrogate fuel was released. On the basis of the results of small-scale fuel characterization experiments which had been conducted separately, it was determined that a release of three grams of surrogate fuel was equivalent to a maximum release of 17 grams of irradiated fuel. Using the CRAC computer code for health consequences (the second of the computer codes used in SAND 77-1927 and NUREG/CR-0743 and a code which generally predicts higher health consequences than the METRAN code) and again assuming 150-day cooling, researchers found that the average radiological consequence of a 17-gram release in a heavily populated area such as New York City would be no early fatalities and about 2 latent cancer fatalities.[1] The peak consequences appearing in the computer runs were no early fatalities and about 7 latent cancer fatalities. Values of average or peak consequences should be doubled to account for the case of a three-assembly truck cask.

Conceivably, an adversary could use more than one shaped charge in attacking a cask, and that possibility was considered. For shaped charges the size of the reference charge, the likely result is that the release would be in proportion to the number of charges used. The use of larger shaped charges is conceivable but less credible. These types of charges would probably have to be custom-made, thereby introducing a formidable new problem for an adversary. There is no known technology that would allow a disproportionately large increase in production of respirable particles with credible increase in a saboteur's explosive resources.

Most consequence calculations discussed herein are based on fuel subjected to burnup of 33,000 megawatt days per metric ton of heavy metal (MWd/MT) at a power density of 40 kilowatts per kilogram of heavy metal (KW/Kg), which is termed reference fuel. The possible transport of spent fuel subjected to higher burnup was considered, although these shipments are not now being made. For fuel subjected to 40,000 MWd/MT (which is typical of the higher burnups being considered) at a power density of 36.4 KW/Kg, the calculated consequences of successful sabotage are about 45 percent higher than the consequences of successful sabotage of reference fuel.

Additional information on the NRC-sponsored program can be found in a report entitled "Final Report On Shipping Cask Sabotage Source Term Investigation." Additional information on the DOE-sponsored program can be found in a report entitled "An Assessment of the Safety of Spent Fuel Transportation in Urban Environs." A peer review of both research programs was carried out by the U.S. Army's Ballistic Research Laboratory. The review focused on the interaction between explosives, cask, and fuel and on the experimental techniques used. The conclusions in the peer review report generally confirm the reasonableness of the approaches taken in the research, and based on the assumptions of the research approach, confirmed the estimated release levels. The two research reports, the peer review report, and SAND 77-1927 are available for inspection at the NRC Public Document Room, 1717 H Street NW., Washington, DC. NUREG/CR-0743 is available from the NRC/GPO Sales Program, U.S. Nuclear Regulatory Commission, Washington, DC 20555.

Conclusions

For the following reasons, the Commission concludes that moderation of the current interim rule (10 CFR 73.37) for the protection of spent fuel shipments against sabotage is justified:

1. Issuance of the interim rule was based chiefly on consequence estimates set forth in SAND 77-1927. A baseline estimate, a high estimate, and a low estimate were provided. At the time the rule issuance was under consideration, the high consequence estimate was based on 14,000 grams of respirable release for a truck cask containing three fuel assemblies and on 47,500 grams of respirable release for a rail cask. At the time, the high-estimate releases could not be ruled out. The calculated average consequences for truck cask sabotage were summarized as several tens of early fatalities and hundreds of latent cancer fatalities. The calculated average consequences for a rail cask were summarized as hundreds of early fatalities and thousands of latent cancer fatalities. The research recently completed has shown that the likely respirable release from sabotage and the resulting consequences are but a tiny percentage of the estimated values which originally prompted issuance of the rule. Accordingly, the original basis for the rule is no longer valid.

2. The value of consequence now predicted (no early fatalities and about four latent cancer fatalities average for reference basis sabotage of a three-assembly cask) is obtained only when a set of assumptions very favorable to the saboteur are made. The effects of assumptions less favorable to a saboteur are discussed below:

a. *Fuel burnup and cooling.* Consequence calculations are based on reference fuel cooled for 150 days. Because of lower burnup and longer cooling, assemblies currently being shipped typically contain a radioactive material inventory 0.2 to 0.5 as hazardous as the assumed inventory for reference fuel.

b. *Population density.* The release of radioactive material was postulated to take place within an area with population density in the range between 62,000 and 200,000 persons per square mile. Very few (perhaps only one) locations in the U.S. are characterized by this population density. Consequences decline markedly for lower population density.

c. *Lifetime of respirable particles.* A respirable particle tends to adhere to the first sizeable particle it encounters or to serve as a condensation site for vapors (such as water), thus possibly limiting its lifetime to one that is shorter than that necessary for human inhalation and deep deposition in the lung. In an actual sabotage, products of the explosion would undoubtedly provide numerous larger-than-respirable particles that would act as agglomeration sites for respirable particles. In both sets of experiments, the products of the explosion were isolated from the cask to keep the measurement problems manageable. Water particles (fog-like droplets) would also serve as agglomeration sites. Finally, water vapor or materials vaporized by the explosive earlier do not account for a water jacket or annulus of wet material present in all truck casks now in use. An experiment has shown that the presence of water (water jacket and water-filled cavity) between the explosive and the fuel reduces the quantity of respirable material released by a factor of 40.

Simultaneous occurrence of worst- or near-worst-case values for each of these factors, plus an assumption of successful sabotage appears remote in the extreme.

[1] The current CRAC code that is cited here (sometimes referred to as CRAC 2) is a modified version of the code that was used in SAND 77-1927 and NUREG/CR-0743. The modified version predicts consequences a few percent higher than the earlier version; the estimated consequences are based on this modified version.

Calculated consequences reported herein are reduced by factors of up to hundreds if values other than the most favorable are assigned.

3. Although the experiments have reduced the uncertainty in the quantity of material likely to be released as a result of successful sabotage, there are limitations to the conclusions of the program that must be taken into account. The reduced consequences described herein are necessarily subject to several assumptions, including that of a reference explosive. While the shaped charge selected for the explosive threat represents a very severe threat, even more severe threats cannot be ruled out if an adversary is granted protracted control of a shipment and unhindered movement. In a similar vein, consequence modeling assumptions more severe than those postulated in NUREG/CR-0743 can also be conjectured (e.g., localized areas, such as stadiums, with extremely high population densities), if completely unrestricted movement of the shipment and unrestrained use of sabotage resources against the shipment are allowed. For these reasons a set of moderate requirements that would continue to provide a significant level of protection against protracted loss of control of a shipment and unhindered movement of a shipment by a saboteur is being considered. The requirements should (a) deny an adversary easy access to shipment location information; (b) provide for early detection of malevolent moves against or loss of control of a shipment; (c) provide a means to quickly summon assistance from local law enforcement authorities; and (d) provide a means to impede unauthorized movement of a truck shipment into a heavily populated area.

Summary of the Proposed Rule

A rule is proposed that takes into account the new information and conclusions which have emerged from the research program. The important features of the proposed rule are:

1. The performance requirements for protection of spent fuel shipments have been modified to emphasize protection against sabotage with high consequence. High consequence refers to the levels of consequence that prompted issuance of the original interim rule. For a truck shipment, high consequence refers to tens of early fatalities and hundreds of latent cancer fatalities.

2. For shipment of spent fuel cooled less than 150 days, the current requirements would continue to apply, because detailed consequence calculations for such fuel have not been carried out.

3. For shipments of spent fuel cooled 150 days or more, a new set of moderate requirements would apply that are consistent with the experimentally determined level of consequence. The requirements call for a shipment to be accompanied by an unarmed escort (who may also serve as driver, rail employee, or ship's officer) who would carry out prescribed security procedures. In addition, present requirements for protection of shipment schedule information, onboard communications (all transport modes), and immobilization (truck mode only) would be retained.

Among other requirements considered no longer needed (for shipments of fuel cooled 150 days or more) are those for route surveys and advance coordination with local law enforcement agencies (LLEAs). New DOT requirements for routing (49 CFR 177.825) issued in the interest of safety and recently put in force apply to NRC licensees and require them to use routes consistent with NRC safeguards routing policy. With respect to LLEA coordination, a separate NRC rule (the present § 73.37(f)) requires the notification of governors (or designated state officials) whenever spent fuel is to be transported within a state to enable the state to contribute to the safety, security, and ease of transport of the shipment. State LLEAs typically are informed of impending shipments through this process.

Environmental Impact: Negative Declaration

The promulgation of these amendments would not result in any activity that affects the environment. Accordingly, the Commission has determined under the National Environmental Quality guidelines and the criteria of 10 CFR 51.5(d) that neither an environmental impact statement nor environmental impact appraisal to support a negative declaration for the proposed amendments to Title 10 is required.

Paperwork Reduction Act Statement

This proposed rule amends information collection requirements that are subject to the Paperwork Reduction Act of 1980 (44 U.S.C. 3501 et seq.) by reducing the burden. This rule has been submitted to the Office of Management and Budget for review of the proposed revised paperwork requirements.

Regulatory Flexibility Certification

Based on the information available at this stage of the rulemaking proceeding and in accordance with the Regulatory Flexibility Act of 1980, 5 U.S.C. 605(b), a significant economic impact upon a substantial number of small entities. The rule, if promulgated, would apply to licensees who transport or deliver to a carrier for transport a shipment of spent fuel in a quantity in excess of 100 grams. Typical of the licensees who deliver spent fuel to carrier for transport are nuclear power reactor operators, independent spent fuel storage pool operators, and research institutions. None of the licensees who deliver spent fuel to a carrier for transport are known to be small entities. Licensees who transport spent fuel are typically large carriers who specialize in the transport of radioactive materials and other hazardous materials and who have many employees. No small entities are known to be within this licensee group.

The NRC has estimated the cost impact of these amendments upon the licensed industry. According to these estimates licensees would incur the following costs, assuming continuation of the current approximately 135 shipments annually. One-time costs for the proposed amendments have already been expended due to the same requirements under the present interim rule. Annual maintenance cost of equipment required by the proposed amendments is estimated at $14,000. Annual planning and administration cost is estimated at $7,000. Total cost to licensees is therefore estimated at $21,000 annually.

One savings to industry under the proposed amendments would be the elimination of about $27,000 expended annually for armed escorts presently required under the interim rule. Simplification of administration is estimated to result in an additional saving of $13,000 annually. Further information regarding these estimates is set forth in a document entitled "Modification of Protection Requirements for Spent Fuel Shipments: Regulatory Analysis" and is available for inspection and copying in the NRC Public Document Room, 1717 H Street NW., Washington, D.C.

Any small entity subject to this regulation which determines that because of its size, it is likely to bear a disproportionate adverse economic impact should notify the Commission of this in a comment that indicates:

(a) The licensee's size in terms of annual income or revenue and number of employees;

(b) How the proposed regulation would result in a significant economic burden upon the licensee as compared to that on a larger licensee; and

(c) How the proposed regulations could be modified to take into account the licensee's differing needs of capabilities.

Public Comment Solicited

Although it welcomes public comment on any aspect of the proposed regulation, the Commission particulary solicits comment on the following topics:

1. Is more research justified for safegurads of shipments of spent fuel cooled less than 150 days before shipment?
2. Should the NRC simplify its safeguards regulations by prohibiting shipment of fuel cooled less than 150 days before shipment?
3. Are the NRC cost estimates in accord with licensee experience?

List of Subjects in 10 CFR Part 73

Hazardous materials—Transportation, Incorporation by reference, Nuclear materials, Packaging and containers, Penalty, Reporting requirement.

For the reasons set out in the preamble and under the authority of the Atomic Energy Act of 1954, as amended, the Energy Reorganization Act of 1974, as amended, and 5 U.S.C. 553, notice is hereby given that adoption of the following amendments to 10 CFR Part 73 is contemplated.

PART 73—PHYSICAL PROTECTION OF PLANTS AND MATERIALS

1. The authority citation for Part 73 is revised to read as follows:

Authority: Secs. 53, 161, 68 Stat. 930, 948, as amended, sec 147, 94 Stat. 780 (42 U.S.C. 2073, 2167, 2201); sec. 210, 88 Stat. 1242, as amended, sec. 204, 68 Stat. 1245 (42 U.S.C. 5841, 5844).

Sections 73.37 (g) and (h) are also issued under sec. 301, Pub. L. 96–295, 94 stat. 789 (42 U.S.C. 5841 note).

For the purposes of sec. 223, 68 Stat. 958, as amended (42 U.S.C. 2273); §73.21, 73.37(h), 73.55 are issued under sec. 161b, 68 Stat. 948, as amended (42 U.S.C. 2201(b)); §§ 73.20, 73.24, 73.25, 73.26, 73.27 73.37, 73.40, 73.45, 73.50, 73.55, 73.67 are issued under sec. 161i, 68 Stat. 949, as amended (42 U.S.C. 2201(i)); and §§ 73.20 (c)(1), 73.24 (b)(1), 73.26 (b)(3), (h)(6), and (k)(4), 73.27 (a) and (b), 73.37 (g) and (h), 73.40 (b) and (d), 73.46 (g)(6) and (h)(2), 73.50 (g)(2), (3)(iii)(b) and (h), 73.55 (h)(2), and (4)(iii)(B), 73.70, 73.71, 73.72 are issued under sec. 161o, 68 Stat. 950, as amended (42 U.S.C. 2201(o)).

2. Section 73.37 is amended as follows:

a. Paragraphs (a)(1)(i), (a)(2)(iii), and (b)–(e) are revised.

b. Existing paragraphs (f) and (g) are redesignated as paragraphs (g) and (h) respectively and are revised.

c. A new paragraph (f) is added.

73.37 Requirements for physical protection of irradiated fuel in transit.

(a) *Performance objectives.*

(1) * * *

(i) Minimize the possibilities for high consequence radiological sabotage of spent fuel shipments; and

* * * * *

(2) * * *

(iii) Impede attempts at high consequence radiological sabotage of spent fuel shipments or attempts to illicitly move spent fuel shipments containing materials with high consequence potential, until response forces arrive.

* * * * *

(b) *General requirements for protection of shipment of spent fuel cooled for less than 150 days.* The licensee, in order to achieve the performance objectives of paragraph (a) of this section, shall provide for a physical protection system that has been established, maintained, or arranged for fuel that has been used as part of an assembly to sustain nuclear fission in a self-supporting chain reaction at any time during the 150-day period before the date on which the fuel is loaded aboard a transport vehicle for transport. This physical protection system must include the following:

* * * * *

(c) *Shipments by road of spent reactor fuel cooled less than 150 days.* In addition to the provisions of paragraph (b) of this section, the physical protection system for any portion of a spent fuel shipment subject to paragraph (b) of this section that is by road must provide that:

* * * * *

(d) *Shipments by rail of spent reactor fuel cooled less than 150 days.* In addition to the provisions of paragraph (b) of this section, the physical protection system for any portion of a spent fuel shipment subject to paragraph (b) of this section that is by rail must provide that:

* * * * *

(e) *Shipments by sea of spent reactor fuel cooled less than 150 days.* In addition to the provisions of paragraph (b) of this section, the physical protection system for any portion of a spent fuel shipment subject to paragraph (b) of this section that is by sea must provide that:

* * * * *

(f) *Requirements for protection of shipments of spent fuel cooled 150 days or more.* To achieve the performance objectives of paragraph 73.37(a) of this section, a physical protection system established, maintained, or arranged for by the licensee for fuel which has not been used as part of an assembly to sustain nuclear fission in a self-supporting chain reaction at any time during the 150-day period before the date on which the fuel is loaded aboard the transport vehicle for transport shall:

(1) Provide for notification of the Nuclear Regulatory Commission in advance of each shipment, in accordance with § 73.72 of this part;

(2) Include procedures for coping with circumstances that threaten deliberate damage to a spent fuel shipment and with other safeguards emergencies;

(3) Provide that shipments are planned so that scheduled intermediate stops are avoided to the extent practicable;

(4) Provide for at least one escort, who may be a shipment vehicle operator or an officer of the shipment vessel, and who maintains visual surveillance of the shipment during periods when the shipment vehicle is stopped, or the shipment vessel is docked;

(5) Assure that the escort has been familiarized with, and is capable of implementing the security procedures;

(6) Include instructions for each escort that, upon detection of the abnormal presence of unauthorized persons, vehicles or vessels in the vicinity of a spent fuel shipment, or upon detection of a deliberately induced situation that has the potential for damaging a spent fuel shipment, the escort will:

(i) Determine whether or not a threat exists;

(ii) Assess the extent of the threat, if any;

(iii) Inform local law enforcement agencies of the threat and request assistance; and

(iv) Implement the procedures developed in accordance with paragraph (f)(2) of this section;

(7) Provide, for shipments by road, a capability for an escort to communicate with local law enforcement agencies through the use of the following equipment located on the transport vehicle:

(i) citizens band (CB) radio; and

(ii) radiotelephone or other NRC-approved equivalent means of two-way voice communication;

(8) Provide, for shipments by road, NRC-approved features that permit immobilization of the cab or cargo-carrying portion of the vehicle;

(9) Provide, for shipments by rail, a capability for an escort to communicate with local law enforcement agencies through the use of a radiotelephone or other NRC-approved equivalent means of two-way voice communication, which must be available on the train; and

(10) Provide, for shipments by water in U.S. territory, a capability for an escort to communicate with local law

enforcement agencies through the use of radiotelephone or other NRC-approved equivalent means of two-way voice communication.

(g) Prior to the transport of spent fuel within or through a state a licensee subject to this section shall notify the governor or the governor's designee. The licensee shall comply with the following criteria in regard to a notification.

(1) The notification must be in writing and sent to the office of each appropriate governor or the governor's designee. A notification delivered by mail must be postmarked at least 7 days before transport of a shipment within or through the state. A notification delivered by messenger must reach the office of the governor or the governor's designee at least 4 days before transport of a shipment within or through the state. A list of mailing addresses of governors and governor's designees was published in the Federal Register on June 7, 1982 (Vol. 47, No. 109, pages 24671–24673). An updated list will be published annually in the Federal Register on or about June 30.

(2) The notification must include the following information:

(i) The name, address, and telephone number of the shipper, carrier and receiver;

(ii) A description of the shipment as specified by the Department of Transportation in 49 CFR 172.202 and 172.203(d);

(iii) A listing of the routes to be used within the state; and

(iv) A statement that the information described below in § 73.37(g)(3) is required by NRC regulations to be protected in accordance with the requirements of § 73.21.

(3) A licensee shall provide the following information on a separate enclosure to the written notification along with a statement that the information is required by NRC regulations to be protected in accordance with the requirements of § 73.21.

(i) The estimated date and time of departure from the point of origin of the shipment;

(ii) The estimated date and time of entry into the governor's state;

(iii) For the case of a single shipment whose schedule is not related to the schedule of any subsequent shipment, a statement that schedule information must be protected in accordance with the provisions of § 73.21 until at least 10 days after the shipment has entered or originated within the state; and

(iv) For the case of a shipment in a series of shipments whose schedules are related, a statement that schedule information must be protected in accordance with the provisions of § 73.21 until 10 days after the last shipment in the series has entered or originated within the state and an estimate of the date on which the last shipment in the series will enter or originate within the state.

(4) A licensee shall notify by telephone or other means a responsible individual in the office of the governor or in the office of the governor's designee of any schedule change that differs by more than 6 hours from the schedule information previously furnished in accordance with paragraph (g)(3) of this section, and shall inform that individual of the number of hours of advance or delay relative to the written schedule information previously furnished.

(h) State officials, state employees, and other individuals, whether or not licensees of the Commission, who receive schedule information of the kind specified in paragraph (g)(3) of this section shall protect that information against unauthorized disclosure as specified in § 73.21.

Dated at Washington, DC, this 5th day of June, 1984.

For the Nuclear Regulatory Commission.

Samuel J. Chilk,

Secretary of the Commission.

[FR Doc. 84-15400 Filed 6-7-84; 8:45 am]

BILLING CODE 7590-01-M

DEPARTMENT OF THE TREASURY

Bureau of Alcohol, Tobacco and Firearms

27 CFR Part 55

[Notice No. 530]

Information Gathering on Safe Handling of Explosives Materials in the Fireworks Industry

AGENCY: Bureau of Alcohol, Tobacco and Firearms, Treasury.

ACTION: Request for comments.

SUMMARY: The Bureau of Alcohol, Tobacco and Firearms (ATF) is responsible under 18 U.S.C. Chapter 40 for protecting interstate and foreign commerce against interference and interruption by reducing the hazard to persons and property arising from misuse and unsafe or insecure storage of explosives materials. Accordingly, regulations have been promulgated in 27 CFR Part 55, Subpart K, which prescribe standards for the storage of explosives materials.

Nevertheless, accidental explosions causing death, injuries and property damage have occurred at fireworks manufacturing/assembly facilities. Therefore, the Bureau is soliciting suggestions from members of the explosives industry and other interested persons as to whether more effective safety standards are needed in the regulations in order to reduce the hazard to the general public. Suggestions should be forwarded to the address set forth below.

ATF will not recognize any material as confidential. Any materials submitted may be disclosed to the public. Any material which the transmitter considers to be confidential or inappropriate for disclosure should not be included in the suggestion. The name of the person submitting the suggestion is not exempt from disclosure.

DATE: There is no official comment deadline.

FOR FURTHER INFORMATION CONTACT: Arthur Cunn, Firearms and Explosives Operations Branch, 202-566-7591.

ADDRESS: Chief, Firearms and Explosives Operations Branch, Bureau of Alcohol, Tobacco and Firearms, P.O. Box 189, Washington, DC 20044.

Copies of this notice, and all suggestions received pursuant thereto, are available for public inspection during normal business hours at: Office of Public Affairs and Disclosure, Room 4407, Federal Building, 12th and Pennsylvania Avenue NW., Washington, DC 20226.

Signed: June 1, 1984.

Stephen E. Higgins,

Director.

[FR Doc. 84-15478 Filed 6-7-84; 8:45 am]

BILLING CODE 4810-31-M

DEPARTMENT OF THE INTERIOR

Office of Surface Mining Reclamation and Enforcement

30 CFR Part 915

Public Comment Procedures and Opportunity for Public Hearing on Proposed Modifications to the Iowa Permanent Regulatory Program

AGENCY: Office of Surface Mining Reclamation and Enforcement (OSM), Interior.

ACTION: Proposed rule.

SUMMARY: OSM is announcing procedures for a public comment period and for requesting a public hearing on the substantive adequacy of program amendments submitted by Iowa as amendements to the State's permanent

APPENDIX C

Analyses of Cask Sabotage Involving Portable Explosives: A Critique
by
Lindsay Audin

DRAFT

ANALYSES OF CASK SABOTAGE INVOLVING PORTABLE EXPLOSIVES: A CRITIQUE

by Lindsay Audin

DRAFT

Contents

Executive summary

Background on the Problem and Rules

Shipments of spent nuclear fuel involve a large inventory of highly radioactive materials that, if dispersed, could create a major health and contamination problem. While studies had been performed on the potential dispersal due to an accident, only approximate analyses had been done on the releasable quantity (called a "source term") that would result from an intentional effort to breach a cask via terrorist action. A 1978 study found that a 1% release could yield an unacceptably high number of cancer deaths due to inhalation of radioactive particles. To address this hazard, the NRC created interim security rules in 1979 requiring armed escorts, secrecy, coordination with local law enforcement officials, and other measures.

Since the 1978 study was largely theoretical, several experimental studies were performed that involved tests, both scale and full-size, using explosives to damage spent fuel and an out-of-service cask. These experiments appeared to show that much less than 1% of the spent fuel would actually escape from a breached cask and, in 1984, NRC proposed relaxation of its interim security rules. Many interested parties, from the nuclear industry to environmental groups, opposed changing the rules, often for very different reasons, and the interim regulations were left in place.

DOE Involvement in the Security of NWPA Shipments

The advent of the Nuclear Waste Policy Act (NWPA) and the involvement of the DOE in shipping the wastes to a final repository raised new questions concerning cask security, however. DOE had relaxed most of its own security rules based on the tests.Since it would take title to the spent fuel prior to shipping, armed escorts, etc. would no longer be required for shipments of spent fuel from power plants. The validity of the tests then became an important question: did they indeed demonstrate that a sabotage attempt would not create a serious health hazard?

Validity of the Tests

Questions were raised about the test results and analysis, both by respondents to a public comment request and by peer reviewers at a U.S. Army laboratory. Independent examination of the documentation and related studies shows that a number of factors could affect the final source term derived in the sabotage study. Unfortunately, backup data that supposedly detailed some of the questioned aspects has never been assembled or reviewed since the study was done, so a complete critique is not possible. Such poor documentation was one of the problems cited in the public criticism. Other problems included the following:

- The test apparatus could have affected the results in several ways but there was little or no evaluation of this problem.
- The spent fuel samples were 6 1/2 years old and had cooled down significantly. The analysis was designed to address 150-day-old fuel, which will normally self-heat, and the lack of this thermal factor could affect creation of airborne particles.
- The surface crud on the fuel, which is rich in cobalt 60, appears to have been ignored in the source term.
- The reference explosive charge was not the most potentially damaging device available to terrorists. Commercial charges, designed to penetrate steel or destroy rocket boosters, could be more effective. Armor-piercing devices, developed since the tests, could also do more damage.
- The cask chosen for analysis was not the most vulnerable. Other commercial fuel casks and research fuel casks are more easily damaged.
- Some characteristics of spent fuel that could affect the source term, such as grain shattering and chemical reactions, were not fully addressed.

- No effort was made to quantify the vapor component of the source term; this could be especially important in the analysis of an event involving older fuel.
- The computer code used in the consequence analysis was neither appropriate to a transportation incident nor as up-to-date as others that were available.
- Only the respirable component of the source term was evaluated for health effects; the impacts of any other material that escaped the cask were ignored.

Relevance to the NWPA Shipments

While most (if not all) shipments under the NWPA will involve cargoes much older and somewhat less radioactive than 150-day-old spent fuel, many of the problems found in the sabotage study may still apply to the assessment of this hazard. Difficulties with procedures, documentation and peer review alone raise questions about the legal basis for modifying NRC's interim rules. Design changes to the next generation of casks (e.g., more fuel, thinner shielding) may also make them more vulnerable to attack. If indeed the tests do not support less secure shipping procedures, then appropriate legal action is needed to modify NWPA security standards to the proper level.

While the sabotage tests were a necessary start in the right direction, there exists a need to update, improve and verify them, with on-going independent oversight, before their results can be considered acceptable.

Background

While initial environmental analyses of spent fuel shipments (e.g., NUREG-0170) indicated little danger from sabotage, later calculations (i.e., SAND77-1927 and NUREG/CR-0743) found that a potentially serious threat existed, if one assumed a release of 1% of the fuel inventory outside the cask. As a result of this finding, the NRC promulgated an interim rule requiring armed escorts for shipments while they traversed urban areas, as well as other security procedures. Commonly referred to as NUREG-0561, after the publication outlining these procedures, this rule required (in addition to armed escorts in a separate vehicle) all of the following actions:

- radio or telephone communications between the vehicle and a monitoring base every 2 hours while the vehicle was in motion
- prior route approval from the NRC, which verified the location and means to communicate with local law enforcement agencies in event of an attack
- significant advance notice of all shipments to an appropriate state agency (usually a governor's liaison for emergency preparedness)
- tight restrictions on information concerning the shipping route and starting time.

Since the quantification of the threat was based only on theoretical calculations, NRC and DOE cooperated on several laboratory experiments[1,2] to more closely simulate an actual attack with high explosives. Performed between 1980 and 1982, these tests utilized federal and private labs to develop factors that could be used to determine the fraction of spent fuel that could be aerosolized (i.e., converted to a respirable size that would lodge in the lung) during a sabotage attack. The results appeared to indicate that the original 1% estimate grossly exaggerated the possible release.

NRC concluded that some of its restrictions could be relaxed and, in 1984, proposed new rules[3] eliminating the need for armed escorts (but leaving in place most of the other rules). The proposal was not well received by state agencies responsible for public safety or by environmental groups. Even some nuclear utilities and representatives were critical, though usually for different reasons[4]. NRC shelved its proposed changes, with the understanding that its security restrictions remained "interim" until it decided otherwise.

Since it had already received public comment, NRC is under no requirement to make any further announcements should it desire to finalize its proposal (unless the content of that proposal is altered).

It should be understood that spent fuel shipments occur in the United States under control of three separate agencies: NRC (which covers shipments from power reactors and private research facilities), DOE (which is responsible for shipments from government labs and weapons plants) and DOT (which oversees DOE shipments and certain aspects of NRC shipments). Both DOE and DOT promulgated rules that reflected a reduced concern for sabotage after the tests mentioned above. DOE no longer required armed escorts on its shipments, while DOT created its own framework of rules (usually referred to as HM-164, after the rulemaking number[5]) covering both safety and security measures. While DOT required DOE to adopt security rules equivalent to those of NRC, DOT interpreted this to allow the absence of armed escorts. If NRC eliminates its other restrictions, DOT's rules automatically allow DOE to do so, as well.

The final piece of the regulatory puzzle involves shipments under the NWPA. While that law (as amended) requires DOE to follow NRC's prenotification rules, it does not necessitate precise adherence to the other NRC security regulations. However, discussion with OCRWM officials indicated that DOE would be treated by NRC "like any other licensee, like Duke Power, for instance,"[6] implying full coverage of NRC's rules. Since DOE is paying for the shipments, there is reason to believe that pressure could be brought on NRC to finally drop its interim rules, thereby avoiding the cost of security forces and other measures.

Overview of technical issues involved in sabotage tests

Fuel and Rod Characteristics

To fully understand the controversy over the potential dangers inherent in sabotage, a grasp of the physical and chemical processes involved is essential. Nuclear fuel is often perceived as a solid ceramic encased in welded tubing, not prone to leakage even under the extremes of heat and pressure experienced in a nuclear reactor. It is important to realize that different interactions with the fuel will occur, depending upon the medium surrounding it and other factors that are not immediately obvious.

After several years of irradiation, nuclear fuel pellets and their surrounding cladding (i.e., tubing) have experienced a number of changes. The pellets (which are little more than enriched powdered uranium oxide pressed and heated into pellet form) may have swelled and cracked, and a portion of their mass has been converted into radioactive forms of other elements (i.e., isotopes), each having its own capacity for diverse chemical and physical reaction. The cladding (usually a zirconium alloy) may also have microscopic cracks and tiny pits that, under certain conditions, form pin holes open to the fuel. The cladding's surface will be coated with a thin film of particles that have flaked off the inside of the reactor pressure vessel. Commonly called "corrosion products," these particles contain isotopes of cobalt, iron and other metals, and the film they form on the rods is called "crud." Past analyses have found that a fuel assembly may hold a significant radiological inventory in the form of dispersible crud.

Depending on its time out of the reactor, the fuel will also be quite hot, remaining so for several years.

When subjected to high temperatures and pressure in a reactor core, the fuel is submerged in water heavily treated to remove dissolved oxygen and other minerals. While sealed in the cladding, the pellets themselves are surrounded by helium, a gas that will not chemically react (i.e., it is "inert") with the fuel. The pellets do become hot, but that heat is constantly drawn off by the circulating water moving across the cladding.

Neither the rods nor the pellets ever come into contact with air while being heated in the reactor. Similarly, the pressure in the core is uniform and the rods are held by springs in the assembly, so they are rarely subjected to bending stresses, physical shock or vibration. Reactor conditions are controlled to maintain slow changes in temperature and pressure, so fuel assemblies are generally never subjected to thermal shock, or rapid cycles of pressurization or decompression. Handling of the fuel after it is spent also exhibits care, and involves slow movements (always under water), conditioned and cooled water in the storage pool and support by metal baskets when it is inserted into a storage or shipping container.

An attempt to disperse the fuel would likely involve a high explosive device (HED) that must first penetrate a transport cask. Scale model tests show that the best candidate for this initial penetration is a shaped charge designed to focus its energy on a small point, and to fire molten high- velocity particles of metal, along with an intense shock wave[1,2]. Such a device would penetrate one or both sides of the cask, shatter the fuel rods and pellets in its path, and heat the area along that path. The shock and heat involved would loosen and disperse the crud layer and initiate several processes not normally experienced by uranium dioxide and zirconium alloy. At high temperatures in presence of oxygen, both materials will change form. Uranium dioxide UO_2 will "re-oxidize" and become U_3O_8 (its natural form), expanding and forming a very fine powder in the process[7]. Zirconium will literally ignite, vaporizing itself and the crud coating. In doing so, it gives off a great deal of heat, thereby initiating or enhancing other processes that require thermal input (such as uranium re-oxidation). The fuel pellets may also shatter back to the consistency of the uranium powder involved in their manufacture. Several of the isotopes formed in the nuclear reaction will also be affected by heat in the presence of air. Ruthenium, for example, will vaporize and combine with oxygen to form minute particles, while other elements, such as iodine, will be released as gases (some of which already exist in the spent fuel rods prior to an explosive event).

Some of these reactions are enhanced by the fineness of the powdering of the fuel, demonstrating the interaction of the processes themselves. Finally, some isotopes will chemically combine with each other (both before and during an event) to form additional compounds (e.g., plutonium iodide) having their own unique characteristics.

Analyzing the Results of a Sabotage Event

Measuring the conditions and results of a rapid and intense explosion can be quite difficult, especially if the dispersed substances are poisonous to the examiner. To examine the dispersal potential of damaged spent fuel involves development of a secure way to damage real fuel rods and compare the results to simulated rods undergoing the same stresses. It is then possible to damage simulated rods in a setting very similar to a real cask sabotage incident and extrapolate the results back to spent fuel were it to be in the same setting. Such a setting must be carefully designed and instrumented so that it measures the magnitude and distribution of particle sizes, as well as the temperature, pressure and other variables needed to verify the realism of the test. It is especially important that the test conditions and apparatus not influence the results of the simulation.

To be sure that the simulation has not been affected usually requires more than one test, with more than one apparatus, to discern the sensitivity of the experiment to its surroundings. Failure to do so leaves open the possibility that a real sabotage event could prove significantly different from the simulation. Since real fuel rods are not used in the simulation, it is necessary to assume an inventory of actual nuclides as input to the computer analysis of radiation exposures. That input should accurately reflect the quantity and distribution of isotopes to properly quantify the radiological impact of the release. Finally, it is essential that the extrapolation of simulated fuel rods to real fuel rods demonstrate attention to the characteristics of the fuel as it is to be analyzed by the computer program. For example, if 150-day-old fuel is assumed at one point in the analysis, then 150-day-old fuel rods must be used to develop the extrapolation. The only alternative is to come up with factors to compensate for the differences between 150-day-old fuel and the older fuel actually used in bench-scale tests. This requires correcting fo: temperature, internal gas pressure and any other variables that change with age. The simulated rods must also have the same cladding material, thickness dimensions and grouping to eliminate any effect those variables could have on the test.

Technical Deficiencies in the Sabotage Tests

Structure of the Tests

While the rulemaking documentation discusses the tests as though they were an integrated effort, there were really two unrelated series of tests, one by DOE labs (Sandia and the Idaho National Engineering Laboratory, known as INEL) and the other by an NRC contractor lab (Battelle Columbus Laboratory, known as BCL). The DOE tests involved destructive evaluation of irradiated and fresh fuel rods at INEL and explosive attacks on scale models and a full sized cask containing fresh fuel rods at Sandia. The Battelle tests used fresh and irradiated fuel rods in highly simplified simulated casks. Each set of tests attempted to do two things:

- develop a ratio of the masses of respirable particles derived from shattering fresh fuel to that obtained by an identical shattering of spent fuel
- determine the mass of respirable fuel particles that would escape from a cask punctured by a shaped charge. The Sandia analysis then went on to assess the health impact of the respirable release in terms of latent cancer fatalities. No other parameter (e.g., decontamination cost) was utilized to quantify the damage of a sabotage incident.

The testing apparatus used in all the tests were similar: sealed chambers containing the target (cask and/or fuel) and a "gun" attachment through which the explosive charge was aimed at the target. Each chamber contained measuring/sampling devices to determine the quantity and size distribution of the fuel particles immediately after the fuel was shattered. In some cases, x-ray photos were taken of the shock wave as it penetrated the fuel rods for more detailed examination of the physical mechanisms at work.

The explosive charges in the sub-scale tests were all designed to replicate the reference explosive assumed to provide the most serious likely threat, that being an M3A1 platter charge. This device is a military explosive that uses a conical shaped charge (CSC) designed to focus its explosive impact into a narrow beam containing molten metal (usually iron). The beam consists of compressed, high-temperature gases that form a series of high-velocity shock waves. When striking a surface, the shock waves and high-temperature gases may be sufficient to disrupt concrete and melt steel, while the impact of the molten particles will penetrate armor plate by transferring to it their heat and kinetic energy. The M3A1 was designed for destroying steel-reinforced concrete bunkers, highways and other stationary facilities.

Weighing about 45 pounds, it can be carried and emplaced by a single soldier.

The fuel rods used in the two sets of tests (Sandia/INEL and BCL) were similar: both INEL and BCL used spent fuel from the H.B. Robinson power plant reactor, aged 6 1/2 years after irradiation, and all three labs used fresh fuel pellets of about the same size. INEL shattered pellets of both fresh and spent fuel, while BCL shattered segments of zircalloy clad fuel rods containing the pellets. Sandia used a segment of a zircalloy-clad fresh fuel assembly for a PWR reactor in its full-scale test.

On the other hand, the sub-scale casks used by Sandia and BCL varied significantly. Sandia's containers appear as scale models of actual casks, cylindrical in shape, consisting of layers of steel and lead surrounded by a water jacket (simulating a water neutron shield). BCL's casks were much more schematic: a flat 1 3/4" thick inner layer of steel was used to simulate the exterior shell of a cask, and a 1/4" thick inner layer of steel simulated the inner shell. No radiation shields (i.e., lead and water) were involved.

The Sandia analysis included use of the CRAC computer program to estimate the health impacts of a release, while the BCL analysis stopped at comparing the respirable release to that assumed in the 1978 study that led to NRC's interim security rules. The CRAC code was designed for releases beyond the boundaries of a nuclear power plant, and does not address dispersions in very close proximity to damaged fuel. Alterations were made to the input data to overcome this limitation. The assumed inventory of radionuclides used by Sandia was that of 150-day-old fuel as utilized in the original 1975 Rasmussen study of a reactor meltdown (NUREG 75-014, also known as WASH-1400).

Questionable Aspects of the Tests

Trying to simulate a complex phenomenon that lasts only a few seconds, involving extremely hazardous substances, high temperatures and pressures, and a spectrum of particle sizes created by a range of simultaneous physical processes is indeed a difficult task. Without numerous verification tests, the best result one can hope to attain is an order of magnitude estimate of the respirable release fraction. In essence, that is what resulted from the BCL and Sandia/INEL tests. Confidence in such a result can be high when there are no major irregularities in the tests, or only a small number of minor irregularities, and if the simulation of reality is reasonable.

Unfortunately, both sets of tests exhibit a lack of attention to quality control, numerous anomalies in their data, oddities in their test apparatus and deficiencies in their radiological analysis. The peer review of the tests is also incomplete, and documentation on details of the tests remains unavailable for public inspection.

Temperature and Age of Fuel

Perhaps the most glaring example of poor quality control was in the choice of the irradiated fuel test specimens. Fuel that has cooled 6 1/2 years is barely warm, but fuel only 150 days out of the reactor will normally maintain a temperature of about 500°F while in the cask (sometimes higher, depending on cask design). The pressure of the gases in the rods is therefore much higher, and the hot fuel pellets may re-oxidize (and turn to powder) when exposed to air[8]. Use of cool fuel eliminates several important physical mechanisms associated with temperature, all of which could worsen the hazard of a cask breach. Another of those mechanisms involves ignition of the zircalloy cladding. Once heated to about 1500°F, zircalloy and air combine in an exothermic reaction that, in a confined space, can be self-sustaining.

The cladding could continue to burn down and across the fuel rods, thereby re-oxidizing fuel into powder, vaporizing cesium and other potential volatiles, considerably increasing the source term. Furthermore, fuel cooled for several years no longer contains some isotopes that are chemically reactive. Once these isotopes have decayed to other elements, there is no way to know how they could influence particle formation and/or disproportionation of themselves or even more dangerous nuclides.

Crud as Part of the Source Term

No attention was paid to the cleanliness of the fuel cladding. After 6 1/2 years of water storage where circulating chemical treatment is common, plus sample handling and cutting, it is likely that a portion of the exterior crud has been removed. None of the tests paid any attention to the crud aspect of the source term: BCL never considered measuring it and INEL used pellets already removed from the cladding. A 1980 NRC-sponsored study[9] (performed at Sandia) found that release of the cobalt 60 in the surface crud could lead to a major radiation dispersal, potentially causing billions of dollars in contamination damage. Prior studies have found that crud can be released under shock, and will flake off in air as cool as 212° F. Particle sizes are in the respirable range[10].

Sabotage Scenario

Poor control was also evidenced in assumptions regarding the sabotage scenario, type of cask and fuel, and choice of the reference charge. It does not appear that anyone (including the Army peer reviewers) considered the real life events that could unfold during an attack and its followup. To take temporary control of the cask, it is likely that some violence, and probably shooting, will occur. The truck fuel tanks may have been punctured, so the area may be soaked in fuel that could be ignited by the flash of the HED explosion. Alternately, a sophisticated terrorist may know the sensitivity of exposed fuel pellets to heat and purposely arrange ignition of the truck fuel and/or other combustibles to aid greater disruption and dispersal. Coming upon the fire, most fire brigades would attempt to extinguish it, thereby adding other mechanisms (e.g., steam flashing and water flow) for dispersal. The ease with which a greater source term could occur was highlighted during one test when merely bumping the shattered rods during removal significantly increased the amount of shattered material available for release[2].

Cask Vulnerability

The cask assumed to be most vulnerable was the NFS-4, also known as the NAC-1. The Sandia analysis examined only casks used for shipping commercial nuclear fuel from PWR or BWR power plants, and excluded the TN-9 (even though it was felt to be more vulnerable) because it was a foreign cask not used in the United States at the time of the study. Ironically, the NFS-4/NAC-1 casks were subsequently withdrawn from service (and only returned for very limited use years later for moving fuel from a Canadian research reactor), while the TN-9 has been used in extensive shipping campaigns in the populous northeast states. If the examination of casks had included all those available for use at the time, it would have found numerous smaller containers used to move highly irradiated research fuels that are much more vulnerable due to their thin aluminum cladding, shape and alloying. One such container, the MH-1A, was actually used to ship spent fuel through New York City in 1985 (a year after the NRC considered withdrawing its security rules) until it was permanently withdrawn when its design defects became the subject of an investigation by the U.S. Department of Transportation.

Reference Charge

The choice of a reference charge did include attention to various possible weapons, but resulted in a device that was not designed for penetrating thick layers of metal. The M3A1 is more of an all-purpose explosive, rather than a system designed for puncture of steel. More inclusive research would have found commercial explosives, smaller in size and more readily available than military hardware, specifically designed to penetrate up to 14 inches of steel, yet weighing much less than the M3A111. The potential for numerous (and more thorough) penetrations therefore exists. Perhaps the most lethal of these commercial devices is an offshoot of the American space shuttle program. To abort the operation of its solid fuel boosters, the outboard engines of the shuttle contain small conical-shaped charges to shatter the rockets, and an exothermic pellet that "smears" through the damaged solid fuel, fully igniting it so that it burns out before returning to earth[11].

Such a device would present a major threat by adding a sustained, very high temperature (over 3,000° F), thermal component to the sabotage incident.

Claims (by Sandia) that the heat of the blast was too short (or too cool) to yield nuclide vaporization or uranium re-oxidation therefore cease to be relevant.

Since the tests were performed, other more potent (and portable) devices have become available to pierce armor. Anti-tank weapons that can be carried and fired by a single soldier are able to penetrate several inches of hardened steel and composite materials much more resistant to puncture than the steel shells of a spent fuel cask. These systems resemble spears with sharp tips of depleted uranium that puncture the outside of a tank, and contain shaped charges that explode after penetrating the armor[12]. In the hands of a saboteur, such equipment could do much more damage than a single M3A1. The fact that it is fired from a distance also opens the possibility of multiple openings in the cask since the saboteur need not approach a cask already leaking from an initial attack. Recent experiences in the Middle East demonstrate that terrorists have access to such portable weapons via sponsoring states or by contact with American-supported guerrillas in Afghanistan. Such a threat cannot be ignored in any realistic analysis of possible sabotage scenarios.

Taken together, these examples of poor selection and limited research should be sufficient to make the value of these tests suspicious, at best. However, the tests themselves exhibit problems of an even more serious nature.

Effects of Chamber Size

The Sandia chamber was so small (compared to the size of the full-scale cask) that it may have affected the measurement of the respirable fraction. Sandia's own analysis found that particles tended to rapidly agglomerate in the air, depending on their density. When respirable particles agglomerate prior to measurement, they may appear to be too large to be respirable, and may rapidly settle out of the air being sampled. No attempt was made to determine if a larger chamber could have better replicated the open outdoors, where agglomeration is far less likely.

Limitations on Test Charge

During the last BCL test on fresh fuel, a particularly "energetic" scaled down version of the M3A1 was so powerful that it blew out a hole in the test chamber (after penetrating both sides of the simulated cask). Since such a result with spent fuel could prove dangerous to the technicians (as well as making impossible any accurate measurement of a dispersal), the BCL test apparatus was altered. Instead of accepting the possibility that a scaled down M3A1 was capable of such a major cask breach and strengthening the test chamber, BCL decided to weaken the explosive impact by placing (in all tests to follow) a 2-inch-thick steel "conditioning plate" into the path of the explosive's shock wave before it reached the surrogate cask's outer shell[2].

Recall that the simulated cask outer shell was only 1 3/4 inches thick; the conditioning plate therefore may have considerably weakened the explosive jet. Again, no sensitivity analysis was performed to determine the impact of this action. The extra 2 inches of steel may have also absorbed a considerable amount of the thermal output of the jet, so it is arguable if the final result of the BCL tests could be considered an accurate scaling down of the impact of an M3A1 charge.

Grain Shattering

The INEL tests on spent fuel pellets revealed a potentially important mechanism for creation of respirables. One of the shattered pellets broke down into a powder whose particle size was the same as the uranium grains used in the pellet's manufacture. When pellets shatter this way, their respirable fraction increases by a factor of 100 or more[1]. The assumed basis for this phenomenon was "grain swelling," a characteristic of pellets after continuous bombardment by radiation. In some cases, many rods in a group of assemblies have demonstrated this problem due to manufacturing problems, and it cannot be assumed to merely be a "fluke." Since only a few pellets were tested, averaging this one pellet with the others may have skewed the results too much or too little. Again, some sensitivity analysis is essential to assess the impact of this phenomenon on the overall results. If grain swelling becomes more common with high burnup fuels, or after extended dry storage, the respirable fraction could be many times greater than previously calculated, making the results more comparable to the hazard initially conceived when a 1% release was postulated.

Missing Data

All three sets of experiments also suffered from missing data due to problems with apparatus or measurements. The BCL tests with spent fuel in a simulated cask, for example, involved 15 deposition plates to pick up particles for analysis. While there was significant non-uniformity in the readings, no data was available on 40% of the points. No reason was given for the missing points, and it is doubtful that no deposition whatsoever occurred at those points. Some of the Sandia tests also exhibited missing information. One quarter-scale test did not account for 4.3% of the surrogate fuel pellets mass, which was 10 times greater than the amount measured as an airborne aerosol. The missing material "was believed to be of particle sizes greater than 30 um (1 um = 1 micron) which were deposited, but not collected, on surfaces inside the test chamber." No basis for this conjecture was furnished: if no sample was collected, then there is no way to verify its particle sizes. The potential for a much larger aerosol fraction existed, but was simply assumed by Sandia to not have occurred. Another suspicious aspect of the Sandia tests involved the effort to check the temperature effects on the uranium oxide. X-ray diffractometry was used to analyze the crystal structure of the shattered fuel and should have been able to find any UO_2 (the normal form) that had re-oxidized to U_3O_8 (which would yield particles of respirable size). While this re-oxidization phenomenon occurs slowly at low temperatures (i.e., below 400°F), it occurs much more rapidly at very high temperatures[13]. Examination of non-fuel materials indicates that a peak temperature between 1744°C and 1850°C (3173°F and 3362°F) was attained, so some conversion to U_3O_8 would definitely be expected. But none was found: only physical (not thermal) mechanisms for particle formation were identified by Sandia. No explanation for this anomaly was provided, and it raises questions on the validity of the x-ray diffractometry analyses.

Distribution of Hazardous Isotopes

Two factors influenced the distribution of the most hazardous isotopes in the source term: the concentration of such materials in the spent fuel prior to the explosion, and any disposition to respirable particle formation of the isotopes due to physical or chemical phenomena. Failure to properly address these factors could raise questions about the accuracy of the simulated release.

The crud layer (containing cobalt 58 and 60, manganese 54, iron 59 and chromium 51) appears to have been ignored by the BCL analyses and a close look at the Sandia isotope list shows that it, too, differs sharply from more up-to-date fuel inventories. Not only is the cobalt 60 curie content too low (by a factor of 6), but that problem also exists for other isotopes of a short-lived nature, such as strontium 89, zirconium 95 and niobium 95, all of which exist in the structural parts of the fuel assembly that would be vaporized by the heat of the blast. Of even greater importance (due to their health impacts) are low values of plutonium 239 and 241, americium 241 and curium 242. Other isotopes of lesser hazard are missing completely from Sandia's list[14].

When the fuel pellets were shattered, there was a need to analyze the proportion of isotopes present in particles of 3.5 microns or less (in order to be respirable), or as vapors. Sandia felt that particles would contain the same proportion of nuclides after dispersal as existed in the intact fuel, except for those that could be vaporized (primarily isotopes of ruthenium and cesium). Since the vapors might condense on cask inner surfaces and these isotopes make up only a small part of the hazard of 150-day-old fuel, Sandia did not feel that their "enhanced release" affected the overall risk estimate. BCL, however, performed an extensive analysis of the potential for such disproportional release and concluded that "there appears to be a definite trend toward higher concentrations of fission products in smaller particles." The major isotopes affected by this phenomenon were cesium 134 and 137, ruthenium 106 and cerium 144. While this phenomenon is of secondary importance with 150-day-old fuel, it becomes more important with older fuel as many hazardous, but short-lived, isotopes decay but cesium and ruthenium live on. The differing conclusions between the Sandia and BCL analyses are not resolved in either report or in later NRC or peer review comments. BCL's disproportionation analysis also lacks any attention to one of the larger hazards of "young" fuel, that being strontium 90. Due to technical problems, BCL was unable to separately detect it and it was not included in the analysis.

Lack of Vapor Analysis

Some of the isotopes that would be released by physical and thermal action would vaporize into gaseous compounds, such as iodine and cesium. Vapors would not be captured by the filters set up in both the BCL and INEL spent fuel tests, so these components of the source term were not sufficiently addressed by the experiment. Since some of these elements could be released in disproportionately greater quantities, or even condense on the cooling aerosol particles, there is a need for a more complete examination of them. Again, the temperature of the fuel would strongly influence the potential vaporization of its components, especially in the presence of air. No reason was given for the lack of any method to capture or sample the gaseous aspects of the potential source term. Other tests on breached fuel rods (e.g., at Oak Ridge National Laboratory) utilized techniques for capturing and sampling gases, so the technology was available.

One can only conclude that these studies were a step in the right direction, but insufficient to clarify the isotopic content of respirable particles. Taken together with the apparently incomplete isotopic inventory, it is difficult to have confidence in the calculated hazard of the source term.

Other Irregularities

The use of the CRAC code for a transportation accident, when better software existed (e.g., RADTRAN, PATHRAE) is inappropriate and may skew the results. It would not be difficult or expensive to update this analysis (once other corrections are done) by simply inputing the source term into an up-to-date simulation.

Because respirable particles are difficult to remove, health effects are most likely to be due to those particles, assuming that timely decontamination is available and enforced to remove larger particles. Such particles can lodge in the nasal and throat passages, cling to surfaces, etc., and their gamma emitters will yield a significant exposure before they are removed by natural or artificial processes. Both BCL and Sandia calculated their source terms based solely on the concentration of airborne particles present after the first seconds following the explosion. By multiplying that concentration by the volume of the cask, they developed a total mass of airborne material that could be expected to escape to the atmosphere. In so doing, they ignore the groundshine exposure resulting from particles that would escape but quickly settle on the ground, on buildings, etc., as well as particles that would do damage by direct contact with living tissue. The proportion of these particles leaving the cask will vary with the scenario (e.g., perforation of the rear wall, fire, etc.), but the "worst case" consequence analysis of both laboratories completely ignored any consideration of these hazards.

While sub-scale cask models and the opinion of the peer reviewer[15] indicated that the explosion could penetrate both sides of the cask, the Sandia full scale tests did not. Based on the results with a cask quite different than the NFS-4, Sandia assumed no such rear penetration. This item is important because BCL's analysis of the explosive gas jet (which were much more detailed than Sandia's or INEL's) found that it entrained a significant amount of the shattered fuel. Had the jet penetrated the other side of the cask, it might have carried with it much more fuel, leading to a much larger dispersal of non-respirable particles. Failure to consider this possibility and assess its impact is a major deficiency in the work of the laboratories involved in this analysis.

Many of the questions raised in this section might have been clarified or refined had details of the tests been available for examination. Sandia's report indicates that such data existed in its appendices, which were available in Volume II of its document. When (in 1984) this author requested that volume, he was told it was classified. When an attempt to declassify it was made, he was told it would take months beyond the end of the public comment period. When NRC was told that the public comment period should be extended to allow for this since failure to supply such data could be a violation of the Administrative Procedures Act, he was then told by a DOE official that Volume II had never actually been compiled, so there was no document to supply[16]. The DOE official was unable to explain how a non-existent document could already have been broken into four distinct sections, paginated, and included in a table of contents in Volume I of Sandia's study. Further discussions with DOE officials indicated that the appendices would be compiled at some future date. As of mid-1989, five years later, this work has never been done, nor are there any plans to do so, according to a Sandia official[17].

It is disconcerting to realize that a major security decision could be made using such inconsistent and incomplete analysis when even the supporting data remains unexamined, by either the NRC or any peer reviewer. Should such a decision be imminent, examination of the Administrative Procedures Act and relevant case law is suggested as a possible remedy to the further application of what may be scientific and regulatory incompetence.

Application of the Peer Review Process

The U.S. Army Ballistic Research Laboratory (BRL) at Aberdeen Proving Ground in Maryland was used in 1983 to peer review the results of the BCL and Sandia work. It produced a brief ten-page report[15] which was limited in its support for the results of that work. BRL confined itself to the explosive effects on the fuel since it lacked expertise to evaluate the experimental and analytical techniques to measure the release of radioactive material. Thus, no peer review was ever performed on the behavior of the spent fuel (e.g., physical mechanisms for shattering, vaporization, disproportionation of isotopes, fuel inventory). This fact makes BRL's effort quite incomplete and unacceptable as a true peer review.

BRL also lacked any detailed penetration/damage data relevant to its review because all of it was contained in the unfinished appendices in Volume II of Sandia's study. BRL states: "Such information would permit independent confirmation of conclusions regarding HED performance." The absence thereof then indicates that no such confirmation was ever done.

BRL attempted to integrate the Sandia and BCL findings but found it necessary to place several qualifications on its conclusions. Regarding the potential for perforation of the cask on both sides by a single blast, BRL concludes "that while the IF-200 [the actual test cask used by Sandia] was not perforated in seven full scale tests, the NFS-4 could be perforated since it has about four inches less lead and an inch less steel along its diameter... We believe that entrainment of particles in the jet's wake would enhance release at the jet's exit hole." But in deference to Sandia, it notes that "if we assume that the concentration change [of particles in air] is small over time required to vent the cask, then the difference between perforation and penetration is also small." BRL noted that this "argument [is] plausible, while not conclusive" thereby avoiding direct criticism of Sandia.

When discussing the relation between sub-scale and full-scale tests, BRL concluded that assumptions made by BCL and Sandia "cannot be verified based on testing conducted to date...The fact that both predictions are of the same order of magnitude is a necessary but not sufficient condition to consider the results mutually confirming." When a question arose concerning spent fuel behavior due to irradiation, BRL deferred again: "...we must in this analysis take their data at face value, as we have no expertise in the experimental procedures or analytical techniques employed."

BRL finishes its report by indicating that the blast effects of the M3A1 should not have been ignored by Sandia: "While not part of our analysis or conclusions, we wish to point out that fragmentation and blast effects from the M3A1 might be significant in the urban scenario. This device projects lethal fragments over 100 meters."

NRC's Responses to BRL's Conclusions

NRC responded to the peer review with a 3 1/2-page comment[18] on BRL's final conclusions. Most were general in nature and concerned the choice of the M3A1 and the NFS-4 as appropriate for the analysis.

Much of the discussion covered the simultaneous perforation of the front and rear walls of the cask. NRC passed off BRL's disagreement with Sandia's results by stating that this view only affected Sandia's results because the "BCL experiments all resulted in double-sided penetration and the related consequence calculations take double-sided penetration into account." Since it was assumed that all the airborne particles existing in the cask during the first few minutes after the explosion would eventually leave by the initial penetration, it made no difference, in NRC's view, if they left by one or two holes. There was therefore also no problem with Sandia's tests.

NRC further stated that "we are aware of no physical mechanisms stemming from the reference explosive sabotage event that could lead to an increase in the concentration [of particles in air] with the passage of time" so the initial concentration of airborne particles would be taken as the only index of a release. There are two problems with this rationalization.

First, there is the potential for a fire that would provide hot gases and a thermal source to drive expansion and convection of air inside the cask, thereby creating mechanisms for flow, further dispersal and re-oxidation of exposed fuel particles. This process would be enhanced if there were two holes in the cask since one could serve as entry of air while the other provided an exit for air containing more airborne particles. Second, both BCL and Sandia considered only the particles that were still airborne 12 seconds to a minute after the explosion, thereby ignoring the material that could be sucked out of a cask (via entrainment in the jet's wake) through a rear perforation in the first few milliseconds of the explosion itself.

While much of this material might be too large to lodge in the lungs of nearby victims, it could settle on their bodies, in nasal passages, etc., and provide a significant gamma and beta dose until removed. It would also provide a major groundshine component to emergency workers and law enforcement personnel dealing with the event. Focusing only on the respirable fraction of the release significantly limited the perspective on ways that a cask could release its contents.

The remainder of NRC's views concerned the lack of "mutual confirmation" by the two sets of tests. Such was not a goal of the tests, said NRC, and the results were close enough to show that the threat had previously been quite exaggerated. This was sufficient, in NRC's view, to support the contention that security regulations could be safely relaxed.

Conclusions Regarding the Peer Review

While addressing several aspects of the analyses, BRL was unable to evaluate a number of important aspects of the studies. Its review was therefore incomplete. Overall, the review reads like a reluctant effort to support the plausibility of the laboratories' arguments without becoming involved in the details of the testing procedures. Due to its distinct lack of expertise concerning nuclear materials and radiation, BRL could in no way be considered a "peer" to Sandia or BCL. At best, its review could be characterized as an open-minded, but uncritical, examination by a disinterested, but friendly, agency. In no way could it be considered a peer review within the definitions normally used by professional scientific journals.

Public Comments and Analysis

After publication of the proposed rule changes, the NRC received a number of comments on them. A review of these views shows that they came from three types of sources:

- nuclear utilities and nuclear industry representatives
- state health, safety and environmental agencies
- concerned public interest groups and individuals. Within these categories, the comments were generally of either regulatory or technical concern[4].

Nuclear Industry Comments

Surprisingly, some members of the nuclear trade focused on the public's perception of the armed guards and felt that they should not be removed because doing so would appear as a reduction in security, leading to pressure for state laws requiring them. At this time, HM-164 had not been finalized so such state laws were a possibility; that ruling now bans any extra security forces beyond those required by NRC rules. Some of the industry commenters also pointed out that maintaining secrecy on the shipping dates and routes only added to public fears and - if indeed the shipments were not dangerous, even if attacked - there was therefore no need to maintain such secrecy. Shipping data was easily discerned through various means and NRC's own staff had suggested making it public. (It is not clear why the Commissioners chose to ignore the staff suggestion and kept the data secret.)

Not surprisingly, all pro-nuclear commenters concurred that the test results served as ample basis for dismissing the threat of sabotage. There was no evidence in any public comments that this group had examined the technical aspects of the tests.

State Agency Comments

State agencies were unanimous in demanding no reductions in escorts, and questioned both the need to remove them (also citing their value in the public's perception) and the validity of the sabotage analysis. Most comments were general and had more the character of protest than critique, but several were substantive. The State of Wisconsin Radioactive Waste Review Board and the Michigan Department of Public Health raised these concerns:

- deletion of route surveys and halting coordination with local law enforcement agencies would make difficult any assessment of local emergency preparation and response capabilities
- no attention was given to consequences due to surface water contamination or public reaction even if no immediate deaths occur
- only aerosol distribution was considered: where is groundshine from dispersed solids, or line-of-sight exposure due to the hole in the cask?
- other realistic circumstances exist to worsen consequences: inversion layers, higher population densities, loss of coolant leading to self-heating and nuclide vaporization; hijacking could lead to mechanical (as versus explosive) opening of the cask and later placement to maximize contamination; a suicide bomber could use more or much larger explosives
- scale up of rods from experiment to simulation did not address self-heating or high temperature in the cask just prior to the explosion; would water in the cask be hot enough to flash to steam, thereby creating an additional mechanism for removing particulates?

Other state agencies questioned the validity of the tests on these grounds:

- rail shipments involve two cask targets, each holding 18 PWR assemblies (the sabotage tests covered one truck cask holding one assembly)

- newer casks will house older fuel but have much thinner shells, hold more fuel, etc., and none of these variables was considered.

Public Interest Comments

The most substantive technical questions came from representatives of the environmental community, however. Many of these are echoed in this report's technical critique.

- The reference charge was designed to break up concrete and roadways, not to penetrate steel; much more effective commercial explosives exist that would punch holes in the cask and one is even designed to ignite anything left after the puncture.
- Research fuel casks exist with much thinner steel walls and contain a similar inventory of nuclides in fuel elements that are much more vulnerable; the subject cask therefore did not represent a worst case scenario.
- The peer review and supporting documentation was found to be inadequate and incomplete.
- Quality control of the tests left a great deal to be desired; in some cases, large portions of shattered simulated fuel could not be accounted for, while in others it appears that actions were taken to either ignore important physical or chemical mechanisms, or to mute these effects without any attention to the impact these actions had on the validity of the overall tests.

Final Conclusions

It is not known which comments convinced the NRC to suspend implementation of its rulemaking, but most of the criticisms remain valid today. NRC must either address them or perform new tests to justify a change in its own security rules. DOE on the other hand, based its elimination of armed escorts on the tests and was not required to address the criticisms. Since it is still not clear if DOE will have to follow NRC's security regulations (depending on DOT's definition of "equivalent" security), the deficiencies and applicability (to new casks) of these tests remain as important and open questions.

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THE TRANSPORTATION OF SPENT NUCLEAR FUEL AND HIGH-LEVEL WASTE A SYSTEMATIC BASIS FOR PLANNING AND MANAGEMENT AT NATIONAL, REGIONAL, AND COMMUNITY LEVELS

ATTACHMENT B

THE TRANSPORTATION OF SPENT NUCLEAR FUEL AND HIGH-LEVEL WASTE:

A Systematic Basis for Planning and Management at National, Regional, and Community Levels

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Prepared for
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ABBREVIATIONS

BN	Burlington Northern Railroad
BWR	Boiling Water Reactor
CCP	"Current Capabilities" Scenario
CNW	Chicago and North Western Railroad
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
EIS	Environmental Impact Statement
EM	Environmental Management
FICA	Facility Interface Capabilities Assessment
FRA	Federal Railroad Administration
GA	General Atomics
GE	General Electric
GTW	Grand Trunk Western Railroad
HANF	Hanford
HLW	High-Level Radioactive Waste
HM164	Hazardous Materials Regulation 164
HTG	High Temperature Gas
INEL	Idaho National Engineering Laboratory
LWT	Legal-Weight Truck
MPC	Multi Purpose Canister
MSC	Miscellaneous Spent Nuclear Fuel
MTU	Metric Tons of Uranium
MXR	"Maximum Rail" Scenario
NAC	Nuclear Assurance Corporation
NRC	Nuclear Regulatory Commission
NSP	Northern States Power
NSTI	Near-Site Transport Infrastructure
OCRWM	Office of Civilian Radioactive Waste Management
O-D	Origin-Destination
PSG&E	Public Service Gas & Electric
PWR	Pressurized Water Reactor
RSA	Regional Servicing Agent
RSC	Research Reactor Fuel
SF	Santa Fe Railroad
SNF	Spent Nuclear Fuel
SP	Southern Pacific Transportation Company
SRS	Savannah River Site
TMI	Three Mile Island
UP	Union Pacific Railroad
TVA	Tennessee Valley Authority
WVDP	West Valley Demonstration Project

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SUMMARY

To describe a national shipment campaign in a fashion which provides the inputs needed for risk and impact analysis as well as the information needed for coordinated planning and management requires an integrated assessment process for systematic consideration of at least the following factors:

- Waste origins, storage locations, and shipment sites
- Waste inventory: current and projected
- Waste acceptance startup and rate
- Priorities for waste acceptance and pickup
- Waste shipment groups
- Transportation cask options
- Transportation mode and cask choices by shipment site
- Routing criteria and routing options

Consideration of these factors enables one to provide useful information in response to basic questions regarding the shipment campaign in prospect under legislation proposed in the 104th Congress: e.g., How many cask shipments are expected? In which acceptance/pickup years? On which rail and highway routes? Through which states and communities? Sections 1 through 15 of this report discuss the factors in an integrated assessment process for a national shipment campaign, the assumptions used in this analysis, and the sources and bases for these assumptions. Sections 16 through 20 discuss the results of alternative scenarios involving three sets of transportation mode and cask choices, and two regional routing options. Section 21 illustrates a process for assembly of additional information on route features needed in risk analysis and management of transportation operations.

Three alternative sets of transportation cask choices at 80 shipment sites are considered:

- An assessment of *current capabilities* for cask loading and near-site transportation suggests that 32 commercial plant sites could choose to ship by legal-weight truck—either in currently-available casks for highway transport of uncanistered fuel or in a high-capacity cask such as the GA-4/9, if and when available.

- An *MPC base case* scenario of transportation choices could reduce to 17 the number of commercial sites shipping by legal-weight truck, and encourage 14 sites to use large-capacity rather than smaller capacity rail casks. However, implementation of the MPC base case requires investments to improve loading capabilities and/or near-site transportation at many sites, plus provision of as-yet-uncertified high-capacity transportation casks and canisters.

- A *maximum rail* scenario of transportation choices could reduce to three the number of commercial sites shipping by legal-weight truck. The maximum rail scenario is almost identical to the scenario assumed by DOE in its recent strategy study for transport to a potential repository at Yucca Mountain.

The *current capabilities* scenario results in 79,300 legal-weight truck casks shipped 62.3 million miles on 13,700 miles of the nation's public highways, *plus* 12,600 rail casks shipped 14.0 million miles on 18,800 miles of the nation's railroads. The high-capacity legal-weight truck cask, if available and used consistently, could reduce highway transport to 31,400 casks shipped 14.7 million miles. Implementation of the *MPC base case* scenario with high-capacity truck casks could further reduce highway transport to 6,300 casks shipped 5.7 million miles over 10,200 miles of the nation's public highways. These reductions, however, would require investments to improve loading and/or near-site transportation capabilities at 29 sites, and would also involve increases in rail cask shipments (10 percent), rail cask shipment miles (9 percent), and rail route miles affected (13 percent). Implementation of the *maximum rail* scenario would further reduce highway transport to 1,150 high-capacity casks shipped 1.0 million miles over 4,200 miles of the nation's public highways. These reductions would require further investment in loading and/or near-site transportation capabilities at 14 sites, and it would also involve further increases in rail cask shipments (9 percent), rail cask shipment miles (10 percent) and rail route miles affected (11 percent).

Different phases of the 30-year shipment campaign affect different portions of the nation's rail and highway networks to different extents. For example, truck shipment comprises 35 percent of the 86,600 metric tons shipped under the *current capabilities* scenario of transportation choices, but 66 percent of the 4,400 metric tons shipped in the first three years of the 30-year shipment campaign. Truck shipment comprises 11 percent of the MTU shipped under the *MPC base case* scenario, but 27 percent in the first three years. These differences reflect the loading and near-site transportation capabilities of sites storing fuel with high-priority for acceptance and pickup.

Perspectives on a national shipment campaign tend to correlate with one's position as an origin, corridor or destination community for shipments of highly-toxic and long-lived radioactive materials. Under the *MPC base case* scenario (default routing), seven states comprising two percent of the nation's population are neither origins, corridors nor the destination for shipments of SNF or HLW. Another seven states comprising 18 percent of the nation's population are origins for such shipments but not corridors for shipments from other states. Still another seven states plus the District of Columbia are corridors but not origins for such shipments; these comprise seven percent of the nation's population. Twenty-eight states comprising 71 percent of the nation's population are both origins for SNF or HLW shipments and corridors for shipments originating elsewhere. The major corridor states under the MPC base case scenario (default routing) are Utah (65 sites), Nebraska (60 sites), Wyoming (58 sites), Illinois (47 sites), Iowa (32 sites), Kansas (28 sites), Missouri (27 sites) and Indiana (25 sites).

All shipments converge in Nevada, the destination state and intended permanent storage location for the nation's SNF and HLW. Nevada has about 0.5 percent of the nation's population. Under default routing, truck shipments enter the state on I-15, either from California moving north alongside the Las Vegas Strip, or from Arizona moving southwest through the Moapa Indian Reservation. Accessing US-95 at the interchange locally known as the "Spaghetti Bowl," truck shipments move northwest through rapidly developing Las Vegas suburbs, entering the Nevada Test Site at the Lathrop Wells, in the Nye County community of Amargosa Valley. Rail shipments enter the state on the Union Pacific railroad, either from California moving north alongside the Strip and through Las Vegas and the Moapa Indian Reservation, or from Utah south to the Lincoln County community of Caliente. At Caliente, rail casks would be transferred to heavy-haul trucks for shipment along U.S. highways and state roads, accessing the Nevada Test Site via a newly constructed road across the Nellis Air Force Range (a 162-mile journey), or continuing on public highways along a circuitous route north and west of the Nellis Air Force Range.

Many departures from default routing could occur as states consider designated alternative routes for "highway route-controlled quantities" of SNF and HLW, and as utilities consider alternative railheads for rail shipments and carriers consider implications for rail freight traffic. These departures have implications, some major, others minor, for the national routing system for SNF and HLW shipments—which route segments are affected, when and to what degree. One major option is a "consolidated southern" routing in which truck shipments from the East and Midwest are oriented to I-40 through St. Louis, Oklahoma City, and Albuquerque rather than to I-80 and I-70, and rail shipments are oriented to the Santa Fe lines through Kansas City, Amarillo and Barstow rather than to the Union Pacific through Nebraska and Wyoming or the Southern Pacific through Kansas and Colorado.

The assessment compares cask shipments under default and consolidated southern routing for five rail and five highway route segments in four states (Wyoming, Colorado, New Mexico, and Nevada). Consolidated southern routing could eliminate or substantially reduce rail and highway cask shipments on the selected Wyoming and Colorado route segments and on the Nevada route segments for shipments from the north. At the same time, however, consolidated southern routing would increase rail and highway shipments on route segments through New Mexico, Arizona and California (east of Barstow), and on the Nevada route segments for shipments from the south and alongside the Las Vegas Strip.

The national shipment campaign in prospect under legislation proposed in the 104th Congress involves 80 sites shipping on different schedules, by different modes, using large portions of the nation's major rail and highway systems, over a 30+ year period, through many states and communities which may have widely varying perspectives on the potential risks and impacts, and widely varying resources for planning and coordination with other affected states and with the relevant federal agencies. Policy considerations to limit, divert or manage impacts need to be combined with an integrated assessment process which provides all parties with systematically-developed information on the implications of the shipment campaign at national, regional, and community levels.

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INTRODUCTION

The 1982 Nuclear Waste Policy Act (NWPA) formalized the goal that spent nuclear fuel (SNF) and high-level radioactive waste (HLW) from roughly 80 temporary storage locations in 36 states should be transported to one or perhaps two permanent geologic repositories for permanent disposal. 1987 amendments to the NWPA specified that Yucca Mountain (NV) was to be the site for the nation's single prospective geologic repository and the ultimate destination for these highly-toxic and long-lived materials.

Less clear since 1987 has been the strategy for managing waste until the time that the permanent repository is available. Should it continue to be stored at its current "temporary" locations, and shipped to the permanent repository when it is available? If so, federal government acceptance could be delayed 10, 20 or even more years beyond the 1998 acceptance date promised in 1982. Should it be transported to a centralized above-ground storage facility (which under current law cannot be in the same state as the permanent repository) to await a second shipment to the geologic disposal site? If so, the federal government would have to find a suitable site outside Nevada, and persuade its stakeholders that centralized storage would not become de facto a permanent above-ground repository.

Legislation proposed in the 104th Congress* would deal with these questions by shipping waste early and to Nevada. The legislation directs DOE to accept spent nuclear fuel at specified annual rates beginning not later than November 1999 for transport to a specified destination—a centralized above-ground storage facility on the Nevada Test Site, adjacent to Yucca Mountain. A viability assessment completed in 1998 is intended to provide some assurance that the wastes shipped to Nevada for above-ground storage could ultimately be disposed at a Yucca Mountain geologic repository, and that a second shipment to another interim or permanent site will not be necessary.

Neither Congress nor DOE has developed a plan for implementing the transportation and storage provisions of the proposed legislation. It is uncertain, for example, when shipments would begin, how rapidly they would proceed, what shipment priorities might be, what transportation/storage casks might be available, how utilities would choose among available casks, what routes would prove most acceptable, etc. How would these questions be resolved, and who would be involved in their resolution, at what stage and with what authority, responsibility and capability? How will the risks, "real" and "perceived," be addressed, assessed, and effectively managed? Even the role and accountability of DOE is uncertain, given its recent initiative to privatize the entire civilian spent fuel transportation system, leaving decisions about shipping containers, modes and routes largely up to private contractors.

Though occasional shipments of spent fuel and other highly-radioactive materials (e.g., cesium, naval reactor fuel) have been safely conducted and effectively managed, no land-based shipment campaign of the scale implied by proposed legislation has been conducted in the U.S. or elsewhere. How best to plan for and effectively manage such a campaign in our participatory federal system of governance of the 1990's has not been decided. It is generally assumed that such a campaign would require the coordinated participation of several federal and many state, local, and private agencies—each responsive to its own constituencies. It is acknowledged that these agencies would need to participate in an extensive array of

* Senate bill 1936 (S. 1936), a substitute for the earlier Senate bill 1271. A companion bill (H.R. 1020) is under consideration in the House of Representatives.

activities over many months, years, even decades. It is generally acknowledged that a detailed description of the national shipment campaign, including an inventory of key local conditions potentially affected, is required as the basis for coordinated planning and management. But, though proposed legislation would make an unprecedented national shipment campaign a near-term prospect, such a detailed description is not available as a resource for the many parties which would expect to participate in its coordinated planning and management.

One way to reduce uncertainty is to develop scenarios which reflect specific assumptions regarding relevant factors, and which then provide detailed information (e.g., shipments by cask type, origin, route segment, and year) needed as the basis for planning and management. One purpose of this report is to describe several possible scenarios for the shipment campaign in prospect under S. 1936, and the direct consequences of these scenarios—prospective cask shipments of particular types on particular rail and highway routes in particular years. In the process, the report identifies the several factors and assumptions that underlie any scenario for a national campaign for shipment of SNF and HLW. These factors, combined in an integrated assessment process, suggest the type of information base needed in the planning and management of national shipment campaign—the inputs needed for analysis of risks and impacts, and for identification and resolution of issues ranging from overall campaign efficiency, to regional routing options, to issues specific to particular communities or route segments.

This study applied an integrated assessment system to develop scenarios considering three sets of potential utility transportation choices, two alternative routing strategies and two alternative truck cask options. It will be apparent in review of the factors and assumptions that many other scenarios for the prospective shipment campaign are possible. The integrated assessment process supports the consistent development of alternative scenarios with comparable outputs at the national, regional, and route-segment level.

As introduction to the scenarios, this section discusses the *activities* involved in planning and managing a national shipment campaign, the *agencies* which must coordinate to conduct these activities, the *information* needed as a basis for coordinated planning and management, and the *factors* that must be considered in generating this information.

Activities

To identify the range of activities involved in planning and managing a national shipment campaign, one might consider DOE's May 10, 1996 notice of proposed policies and procedures for implementing section 180(c) of the Nuclear Waste Policy Act regarding training for safe routine transportation and emergency response training.[1] A review of this notice, which summarizes and responds to previous stakeholder comments on the subject, provides a useful list of the activities which will be involved in the transportation of SNF and HLW from about 80 origin sites across the country, along numerous highway and rail routes, across many jurisdictions and communities, over a 30-year period to an interim or permanent storage site in Nevada. The list of activities, only a few of which DOE proposes to support with 180(c) funds, includes:

- route selection
- alternative route analysis
- route risk analysis
- route inspection (highway and rail)
- contingency routing plans
- transportation infrastructure improvements

- shipment notification
- shipment tracking
- shipment escorting
- provision of public information on routing and shipments
- preparation and enforcement of transportation operations protocols
- carrier and shipper compliance reviews
- assessment of state and local capabilities regarding safe routine transport and emergency response
- enhancement and maintenance of state and local emergency preparedness
- enhancement and maintenance of emergency response and recovery capabilities
- awareness training for first-on-scene and first responder personnel
- specialized training for emergency management and recovery personnel
- public information training for route community liaison personnel
- training for hospital personnel, if and as necessary
- waste acceptance scheduling (start date and annual rate)
- waste acceptance prioritization
- transportation cask design, certification, production, and delivery
- cask loading (wet or dry)
- accident notification
- safe parking designation and procedures
- provision of equipment for emergency response, inspection, first response personnel

Agencies

If the activities involved in nuclear waste transportation are numerous and varied, the actors are numerous and varied as well—adding to the need for federal agencies as well as potentially affected states and local governments to have a sound description of and an effective role in planning the shipment campaign in prospect. The actors, whose respective roles and responsibilities have been much discussed but not decided, include federal, state, local agencies as well as utility shippers, contract carriers, and others.

- Federal agencies include:

  — DOE/OCRWM (Office of Civilian Radioactive Waste Management) . . . manager of the Nuclear Waste Fund and responsible for high-level waste management strategy.

  — DOE/EM (Environmental Management) . . . responsible for HLW in the DOE complex, and for the Nevada Test Site Area 25, designated as the site for centralized above-ground storage in proposed legislation.

  — DOT/RSPA (Research and Special Programs Administration) . . . responsible for implementation guidelines for HMTUSA (the Hazardous Materials Transportation Uniform Safety Act).

  — DOT/FHWA (Federal Highway Administration) . . . responsible for implementation of HM164, and for inspection of highway shipments.

  — DOT/FRA (Federal Railroad Administration) . . . responsible for rail inspections and regulation, and for special studies regarding rail shipments.

— NRC (Nuclear Regulatory Commission) . . . responsible for certification of storage and transportation canisters and casks.

— FEMA (Federal Emergency Management Agency) . . . responsible for emergency management and response in transport of radiological materials.

— Coast Guard/Corps of Engineers . . . responsible for regulation of barge shipments and intermodal transfer at barge terminals.

- State agencies include state police and highway patrols, emergency management agencies, utility regulatory commissions, agencies responsible for route designation, radiological health agencies, environmental regulation agencies, etc.

- State agencies need to coordinate with their counterparts in adjacent states and with Indian tribes, perhaps via regional groups.

- State agencies also need to coordinate with local jurisdictions (especially police, fire, and transportation departments) and with utility (and DOE) shippers and their selected carriers.

- Operating under federal and state guidelines, various private organizations are likely to be directly responsible for cask fabrication, truck transport, and/or rail transport. Furthermore, DOE could convey to private industry contractors broad responsibility for planning and managing campaigns for transporting high-level nuclear waste from various sections of the country. A May 28, 1996 notice in the Federal Register[2] indicates that DOE/OCRWM anticipates contracting with private industry for:

  — virtually all aspects of spent fuel acceptance
  — supplying transportation (and storage) casks
  — transportation to a designated storage facility
  — any required intermodal transport or heavy-haul
  — handling uncanistered spent fuel, as necessary.

  Under such contracts—DOE anticipates two or more contractors serving four regions—the private companies would be permitted to:

  — alter the order of spent fuel acceptance (presumably in consultation with utilities) and/or
  — recommend preferred transportation routes (presumably in consultation with states).

Assessment and Management Information Needs

However roles and responsibilities are decided, any federal, state, local agency or contractor will need certain information as a basis for planning, coordination, and management:

— how many cask shipments are expected?
— containing what types of SNF or HLW?
— in what types of casks?
— in which acceptance year?
— from which storage locations?
— by what mode? (rail, highway, barge)
— on which rail or highway route segments?

In sum, though they may focus on topics or geographic areas of particular relevance to their own responsibilities or contributions, any participating agency will need to plan and manage with reference to a detailed description of the shipment campaign, consistently developed at national, regional, and community levels.

Assessment System Factors

To generate such information for a transportation scenario, however, requires an assessment system in which explicit assumptions are made and information systematically generated regarding at least the following factors:

- Waste origins and storage locations (section 1)
- Current and projected inventory (section 2)
- Waste acceptance startup and rate (section 3)
- Priorities for waste acceptance and pickup (section 4)
- Waste shipment groups (section 5)
- Cask options (section 6)
- Transportation choices and choice factors (sections 7 through 11)
- Annual cask shipments (section 12)
- Routing criteria, mapping, and segmentation (sections 13 and 14)
- Routing options: origin-destination pairs (section 15)

Combined in an integrated assessment system, these factors generate information regarding:

- Routes and cask shipments over the 30-year (life of operations) national campaign (section 16).
- Routes and cask shipments at the Nevada destination—the end of the funnel (section 17).
- Regional routing alternatives and consequences for particular routes in various states (section 18).
- Annual cask shipments and the routes involved in various phases of the campaign (section 19).
- Transportation operations requirements—cask shipment miles, cask shipment miles per MTU shipped, cask shipments per route mile affected (section 20).

Assessment of risks, impacts, and policy options requires systematically-assembled information on key features along affected routes, as illustrated in section 21.

Scenarios Considered in this Study

Using an integrated assessment system, this study describes the national shipment campaign for scenarios which differ in utility transportation choices (three alternative sets), routing strategy (a base case and a consolidated southern routing strategy across central and western states) and cask options (two rail casks, plus one of two legal-weight truck casks). Figure 1 summarizes the factors varied and held constant in these scenarios, providing references to relevant sections of the report.

The integrated assessment system can be used to describe in similar dimensions and detail any national shipment campaign which could emerge—e.g., scenarios reflecting a different current or projected inventory, different acceptance rates or priorities for pickup, alternative cask options, different utility transportation choices and/or alternative routing criteria.

Figure I-1. The Transportation of SNF and HLW: Key Assess System Factors and Variables

	SPENT NUCLEAR FUEL	HIGH-LEVEL WASTE
1.WASTE ORIGINS	124 commercial reactors in 34 states Spent fuel from research reactors: General Atomics.... priority ranking DOE: 8 sites Domestic non-DOE: 8 sites Foreign: 3 temp storage sites in US	4 major DOE sites: Hanford (WA) Idaho Nat Eng Lab (ID) Savannah River (SC) West Valley Demo Proj (NY)
STORAGE LOCATIONS	82 pools assoc with individual reactors 20 pools joined by transfer canals 11 pools shared by two reactors 7 pools at offsite locations (3 DOE) 14 onsite dry strg facil (ex & planned)	Same 4 major DOE sites
SHIPMENT SITES	83 sites (4 DOE) in 36 states	Same 4 major DOE sites
2.INVENTORY	Nov'94: 10809 MTU in 59418 BWR assemblies 19149 MTU in 44602 PWR assemblies 86 MTU in HTG, RSC, MSC SNF 30044 MTU total Cumul: 30,682 MTU in 169,675 BWR assemblies 55,931 MTU in 129,517 PWR assemblies 86 MTU in HTG, RSC, MSC, SNF 86,699 MTU total	13789-28372 canisters of vitrified HLW Hanford: 7067-15000 canisters INEL: 704-8500 canisters SRS: 5717-4572 canisters WVDP: 300 canisters
3.ACCEPTANCE START	Annual estimates, w/o specified start yr	Year 15: ie 2015 if 2000 start yr
ACCEPTANCE RATE	Years 1-5: 9100 MTU Years 6-10: 15000 MTU Years 11-15: 15000 MTU	Years 15-20: 4000 canisters Years 21-25: 4500 canisters Years 26-30: 5000 canisters
4.ACCEPTANCE PRIORITY	Oldest fuel (current & projected) first No within utility reallocations No among utility trades	Generally: 1. WVDP 2. SRS 3. HANF 4. INEL
5.SHIPMENT GROUPS	Among acceptance years? No Among assembly types? Yes Among reactor types? No Among waste origins? No	Not applicable (canistered waste)
6.CASK OPTIONS	R125: similar to DOE's 125-ton MPC R75: similar to DOE's 75-ton MPC LWT: legal-weight truck cask T4/9: the GA-4/9 cask, used if available T1/2: similar to the NAC LWT	R100: an adaption of DOE's 125-ton MPC
7.CASK LOADING FACTORS	Design crane capacity (tons) Operating crane capacity (tons) Cask set-down area (max cask option) Cask length requirement (max cask option)	Assume adequate to load R100
8.NEAR-SITE INFRASRUC	Onsite rail ? Operating onsite rail ? Onsite rail upgrade cost Distance to offsite railhead	Assume adequate to ship R100
9.OTHER TRANSPORTATION CHOICE FACTORS	Federal policies Utility choice criteria Changes at or near utility sites	DOE policy Changes at or near DOE sites
10.TRANSP CHOICE DECISION	Four case examples: Monticello Big Rock Point Point Beach Salem/Hope Creek Enrico Fermi	Factors 6-8 determine

Figure I-1 (Cont).

	SPENT NUCLEAR FUEL	HIGH-LEVEL WASTE
11.TRANSP CHOICE SCENARIOS	Current capabilities MPC base case Maximum rail	All rail shipment, using R100
12.CASK SHIPMENTS	BWR/PWR assemblies in shipment group/ cask capacity (partially-filled cask=1) Non-BWR/PWR MTU in shipment group/ MTU per cask (BWR/PWR)	Canisters in shipment group/ 5 canisters per cask (partially-filled cask=1)
13.ROUTING CRITERIA		
Default route/ highway:	HM 164; max use of interstate hwys; Min transit time; two drivers; Pop centers not avoided.	NA
Default route/ rail:	Nearest railhead or designated barge; Min carrier transfer; min transit time; Pop centers not avoided	Same as SNF
Consolidated southern route/ Highway	Uses Interstate 40 west of Okla City, Interstate 15 north to Las V & Yucca Mtn	NA
Consolidated southern route/ rail:	Uses Sante Fe lines west of Kansas City, Union Pacific north to intermodal transfer	Same as SNF
14.ROUTE IDENTIFICATION & MAPPING	Locate designated route segments Identify on base highway/rail maps Route segmentation	Same as SNF
15.ROUTING CASE EXAMPLES	Oyster Creek (NJ) to Yucca Mtn (NV) Fermi (MI) to Yucca Mtn (NV) Browns Ferry (AL) to Yucca Mtn (NV) Cooper Station (NE) to Yucca Mtn (NV) Grand Gulf (MS) to Yucca Mtn (NV) Diablo Canyon (CA) to Yucca Mtn (NV)	NA
16. NATIONAL SHIPMENT CAMPAIGN	Life of Operations Cask Shipments Default routing 3 transportation choice scenarios	Year 15-30 cask shipments Sames as SNF
17. NEVADA IMPLICATIONS	Life of operations cask shipments Default routing Nevada route segments 3 transportation choice scenarios	Year 15-30 cask shipments Same as SNF Same as SNF
18. REGIONAL ROUTING OPTIONS	Life of operations cask shipments Default and So consol routing Selected route segments in: Wyoming (UP and I-80) Colorado (SP and I-70) New Mexico (SF and I-40) Nevada (UP and I-15) 3 transportation choice scenarios	Year 15-30 cask shipments Same as SNF
19.NATL SHIPMENT CAMPAIGN: ANNUAL SHIPMENTS	Current capabil choices/default routing Year 1 cask shipments by origin: Year 2 cask shipments by origin: Year 3 cask shipments by origin: Year 20 cask shipments by origin: Maximum rail choices/default routing Year 20 cask shipments by origin:	All rail shipment/default routing: Year 1 cask shipments by origin: Year 2 cask shipments by origin: Year 3 cask shipments by origin: Year 20 cask shipments by origin:

Figure I-1 (Cont).

20. TRANSP OPER REQUIREMENTS	Life of operations and years 1-3 Cask shipment miles (total and per MTU) Cask shipments per route mile 2 transportation choice scenarios	Year 15-30 cask shipments Cask shipments miles (total) Same as SNF Same as SNF
21.ROUTE FEATURES	Illustrative: Key route characteristics Route conditions Key facilities alongside Administrative boundaries Segment-specific management policies	Same as SNF

1. WASTE ORIGINS, STORAGE LOCATIONS AND SHIPMENT SITES

In common practice, a reactor name may be used to refer to any of several facilities at a site, or to the site itself. Thus, the term "Calvert Cliffs" may be used to refer to either or both of Baltimore Gas and Electric's two nuclear powerplants, to the joined spent fuel pools at those reactors, to the site's concrete module dry storage facility, or the site itself on the Patuxent River near Lusby in Calvert County. In assessment, however, it is useful to maintain a distinction between the facilities which generate spent fuel, the facilities where this waste is temporarily stored, and the sites from which such waste may be shipped to a centralized or permanent storage facility. The same applies to high-level waste at DOE's defense sites and to other nuclear waste requiring geologic disposal.

Spent Fuel Origins and Storage Locations

In its Acceptance Priority Ranking reports,[3] DOE identifies SNF by the reactor from which it was discharged and by its current storage location. For example:

- The 136 BWR assemblies discharged from the Oyster Creek reactor in Ocean County, New Jersey on May 1, 1972 are now stored at Oyster Creek—meaning the spent fuel pool associated with the Oyster Creek reactor.

- The 85 BWR assemblies discharged from the Quad Cities 2 reactor in Rock Island County, Illinois on December 22, 1974 are now stored at Quad Cities 1—meaning the joined spent fuel storage pools for Quad Cities reactors 1 and 2.

- The 509 BWR assemblies discharged from the Dresden 2 reactor near Morris, Illinois on February 19, 1972 are now stored at Morris—meaning that they have been moved to the nearby General Electric spent fuel storage facility.

- The 102 PWR assemblies discharged from the Robinson 2 reactor in Hartsville, South Carolina on May 4, 1974 are now stored at the Brunswick 1 PWR pool—meaning that they have been transported to Southport, North Carolina for storage in the portion of the Brunswick 1 spent fuel pool designed for BWR assemblies.

Thus, there is a distinction between spent fuel origins and storage locations. Origins are nuclear reactors. Storage locations are spent fuel pools which are sometimes shared among two reactors, or joined by a transfer canal, or, increasingly, on-site dry storage facilities such as those at Surry or Calvert Cliffs, or off-site pools such as those are Morris, or the Idaho National Engineering Lab (INEL). Tables 1-1 and 1-2 present the list of spent fuel origins and storage locations used in this assessment.

In aggregate, DOE's listing of spent fuel discharges describes where spent fuel from particular reactors is now stored, and where spent fuel at particular storage locations came from. For example:

- The 2,200 BWR assemblies discharged through November 1994 from the Peachbottom 3 reactor near York, Pennsylvania are all stored at the Peachbottom 3 spent fuel pool, which has capacity to store 3,814 BWR assemblies.

- Of the 808 PWR assemblies discharged through November 1994 from the Oconee 3 reactor in the western corner of South Carolina, 444 (55 percent) are now stored at the Oconee 3 spent fuel pool, 244 (30.2 percent) are in dry storage facilities at the Oconee site, 58 (7.2 percent) are stored at the Oconee 1 spent fuel pool shared by the Oconee 1 and Oconee 2 reactors, and 62 (7.7 percent) are stored at the McGuire 2 spent fuel pool in North Carolina.

- Of the 3,217 spent fuel assemblies stored at GE's Morris facility in Gundy County, Illinois in November 1994, 1,054 (32.8 percent) are BWR assemblies discharged from the Copper Station reactor in Nebraska, 1,058 (32.9 percent) are BWR assemblies discharged from the Monticello reactor in Minnesota, 753 (23.4 percent) are BWR assemblies from the nearby Dresden 2 reactor, 270 (8.4 percent) are PWR assemblies from the San Onofre 1 reactor in California, and 82 (2.5 percent) are PWR assemblies from the Haddam Neck reactor in Connecticut.

- Of the 1,018 spent fuel assemblies stored at INEL in November 1994, 744 (73.1 percent) are HTG assemblies from Fort St. Vrain in Colorado, 177 are PWR assemblies from the damaged Three Mile Island 2 reactor in Pennsylvania, 69 (6.8 percent) are PWR assemblies from the Surry 1 and 2 reactors in Virginia, 18 (1.8 percent) are PWR assemblies from the Turkey Point 3 reactor in Florida, 6 (0.6 percent) are PWR assemblies from the Point Beach 1 reactor in Wisconsin, and 4 are BWR assemblies from Dresden 1 in Illinois and Peachbottom 2 in Pennsylvania.

Waste Origin and Storage Location Assumptions

- **The Current Inventory of Spent Nuclear Fuel**

  As mentioned, spent fuel discharges through November 1994 are identified in DOE Acceptance Priority Ranking reports by the reactor from which the fuel was discharged and by the current storage location. In this assessment, the 30,044 MTU discharged through November 1994 are assumed to remain at their November 1994 storage location until accepted by DOE for transport to an interim or permanent storage facility. We have not attempted to project future transfers of spent fuel among storage locations.

- **Projected Inventory of Spent Nuclear Fuel**

  For the no-new-reactor-orders case in which nuclear reactors are assumed to operate at an assumed percentage of capacity through their NRC license term, DOE forecasts annual discharges through 2042 by the reactor from which the fuel is discharged.[4] In this assessment, we have identified the pool location to which the fuel would be discharged. For example, projected discharges from the Point Beach 2 reactor near Two Creeks, Wisconsin would go to the Point Beach 1 pool shared by Point Beach reactors 1 and 2, while projected discharges from the Comanche Peak 2 reactor near Glen Rose, Texas would go to the Comanche Peak 1 and 2 pools which are connected by a transfer canal. However, we have not attempted to project future transfers of this fuel either to onsite dry storage facilities or to pools at other sites owned by the same utility, or to pools at sites such as Morris or INEL.

- **High-Level Waste Origins and Storage Locations**

  For HLW generated at defense sites, DOE forecasts the projected number of canisters (containing vitrified HLW) which will require disposal in a geologic repository.[5] In this assessment, we assume that the HLW is vitrified, canistered, and stored until pick up at the site at which it was generated.

Shipment Sites

Route analysis requires the identification of a point of origin for each shipment—the place from which the legal-weight truck, heavy-haul truck, rail or barge shipment begins. This assessment associates each storage location with a shipment origin (Table 1-3). For example, spent fuel stored at the separate pools at Arkansas Nuclear's reactors 1 and 2 or at the Arkansas Nuclear dry storage facility all have the same shipment origin. Similarly, spent fuel stored at the connected pools at Calvert Cliffs reactors 1 and 2 or at the Calvert Cliffs dry storage facility all have the same shipment origin.

As will be discussed in Sections 7 and 8, transportation choices are keyed both to the facilities at the storage location (e.g., the characteristics of the separate, shared or joined spent fuel pools, or of the dry storage facility) *and* to the characteristics of near-site infrastructure (e.g., the availability of onsite rail, the distance to an offsite railhead, and the characteristics of the community along the heavy-haul route).

Table 1-1. Originators of Spent Nuclear Fuel or High-Level Waste

#	WASTE ORIGINS:	COMPANY:	STATE	WASTE TYPE	WASTE TYPE	DESIGN CAPAC (MWE)	UTIL STRTUP YEAR	UTIL SHUTD YEAR
1	ARKANSAS NUCLEAR 1	ARKANSAS POWER & LIGHT	AK	PWR	COMM	850	1974	2014
2	ARKANSAS NUCLEAR 2	ARKANSAS POWER & LIGHT	AK	PWR	COMM	912	1978	2018
3	BEAVER VALLEY 1	DUQUESNE LIGHT COMPANY	PA	PWR	COMM	835	1976	2016
4	BEAVER VALLEY 2	DUQUESNE LIGHT COMPANY	PA	PWR	COMM	857	1987	2027
5	BELLEFONTE 1	TENNESSEE VALLEY AUTHORITY	AL	PWR	COMM	1235	????	????
6	BELLEFONTE 2	TENNESSEE VALLEY AUTHORITY	AL	PWR	COMM	1235	????	????
7	BIG ROCK 1	CONSUMERS POWER COMPANY	MI	BWR	COMM	72	1962	2000
8	BRAIDWOOD 1	COMMONWEALTH EDISON CO.	IL	PWR	COMM	1175	1987	2026
9	BRAIDWOOD 2	COMMONWEALTH EDISON CO.	IL	PWR	COMM	1175	1988	2027
10	BROWNS FERRY 1	TENNESSEE VALLEY AUTHORITY	AL	BWR	COMM	1065	1973	2013
11	BROWNS FERRY 2	TENNESSEE VALLEY AUTHORITY	AL	BWR	COMM	1065	1974	2014
12	BROWNS FERRY 3	TENNESSEE VALLEY AUTHORITY	AL	BWR	COMM	1065	1977	2016
13	BRUNSWICK 1	CAROLINA POWER & LIGHT	NC	BWR	COMM	821	1976	2016
14	BRUNSWICK 2	CAROLINA POWER & LIGHT	NC	BWR	COMM	821	1974	2014
15	BYRON 1	COMMONWEALTH EDISON CO.	IL	PWR	COMM	1120	1985	2024
16	BYRON 2	COMMONWEALTH EDISON CO.	IL	PWR	COMM	1120	1987	2026
17	CALLAWAY 1	UNION ELECTRIC CO.	MO	PWR	COMM	1171	1984	2024
18	CALVERT CLIFFS 1	BALTIMORE GAS & ELECTRIC CO.	MD	PWR	COMM	845	1975	2014
19	CALVERT CLIFFS 2	BALTIMORE GAS & ELECTRIC CO.	MD	PWR	COMM	845	1976	2016
20	CATAWBA 1	DUKE POWER COMPANY	SC	PWR	COMM	1145	1985	2024
21	CATAWBA 2	DUKE POWER COMPANY	SC	PWR	COMM	1145	1986	2026
22	CLINTON 1	ILLINOIS POWER CO.	IL	BWR	COMM	933	1987	2026
23	COMANCHE PEAK 1	TEXAS UTILITIES ELECTRIC CO.	TX	PWR	COMM	1150	1990	2030
24	COMANCHE PEAK 2	TEXAS UTILITIES ELECTRIC CO.	TX	PWR	COMM	1150	1993	2033
25	COOK 1	INDIANA MICHIGAN POWER CO.	MI	PWR	COMM	1030	1975	2014
26	COOK 2	INDIANA MICHIGAN POWER CO.	MI	PWR	COMM	1100	1978	2017
27	COOPER STATION	NEBRASKA PUBLIC POWER DISTRICT	NB	BWR	COMM	778	1974	2014
28	CRYSTAL RIVER 3	FLORIDA POWER CORPORATION	FL	PWR	COMM	825	1977	2016
29	DAVIS-BESSE 1	TOLEDO EDISON CO.	OH	PWR	COMM	906	1977	2017
30	DIABLO CANYON 1	PACIFIC GAS & ELECTRIC CO.	CA	PWR	COMM	1086	1984	2008
31	DIABLO CANYON 2	PACIFIC GAS & ELECTRIC CO.	CA	PWR	COMM	1119	1985	2010
32	DRESDEN 1	COMMONWEALTH EDISON CO.	IL	BWR	COMM	200	1960	1978
33	DRESDEN 2	COMMONWEALTH EDISON CO.	IL	BWR	COMM	794	1970	2006
34	DRESDEN 3	COMMONWEALTH EDISON CO.	IL	BWR	COMM	794	1971	2011
35	DUANE ARNOLD	IOWA ELEC LGT & PWR (IES UTIL)	IO	BWR	COMM	538	1974	2014
36	ENRICO FERMI 2	DETROIT EDISON CO.	MI	BWR	COMM	1093	1985	2025
37	FARLEY 1	ALABAMA POWER & LIGHT	AL	PWR	COMM	829	1977	2017
38	FARLEY 2	ALABAMA POWER & LIGHT	AL	PWR	COMM	829	1981	2021
39	FITZPATRICK	POWER AUTHORITY OF NEW YORK STATE	NY	BWR	COMM	821	1975	2014
40	FORT CALHOUN	OMAHA PUBLIC POWER DISTRICT	NB	PWR	COMM	486	1973	2008
41	FORT ST VRAIN	PUBLIC SERVICE CO. OF COLORADO	CO	HTG	COMM	330	1979	1989
42	GINNA	ROCHESTER GAS & ELECTRIC	NY	PWR	COMM	490	1969	2009
43	GRAND GULF 1	SYSTEM ENERGY RESOURCES	MS	BWR	COMM	1250	1984	2022
44	HADDAM NECK	CONNECTICUTT YANKEE ATOMIC POWER	CT	PWR	COMM	582	1967	2007
45	HARRIS 1	CAROLINA POWER & LIGHT	NC	PWR	COMM	940	1987	2026
46	HATCH 1	GEORGIA POWER COMPANY	GA	BWR	COMM	777	1974	2014
47	HATCH 2	GEORGIA POWER COMPANY	GA	BWR	COMM	784	1978	2018
48	HOPE CREEK	PUBLIC SERVICE ELECTRIC & GAS CO	NJ	BWR	COMM	1118	1986	2025
49	HUMBOLDT BAY	PACIFIC GAS & ELECTRIC CO.	CA	BWR	COMM	65	1963	1976
50	INDIAN POINT 1	CONSOLIDATED EDISON OF NY	NY	PWR	COMM	265	1962	1980
51	INDIAN POINT 2	CONSOLIDATED EDISON OF NY	NY	PWR	COMM	873	1973	2013
52	INDIAN POINT 3	PORT AUTHORITY OF NEW YORK	NY	PWR	COMM	965	1976	2015
53	KEWAUNEE	WISCONSIN PUBLIC SERVICE CO.	WI	PWR	COMM	535	1974	2013
54	LACROSSE	DAIRYLAND POWER COOP.	WI	BWR	COMM	50	1968	1987
55	LASALLE 1	COMMONWEALTH EDISON CO.	IL	BWR	COMM	1122	1982	2022
56	LASALLE 2	COMMONWEALTH EDISON CO.	IL	BWR	COMM	1122	1984	2023
57	LIMERICK 1	PHILADELPHIA ELECTRIC CO.	PA	BWR	COMM	1055	1985	2024
58	LIMERICK 2	PHILADELPHIA ELECTRIC CO.	PA	BWR	COMM	1055	1989	2029
59	MAINE YANKEE	MAINE YANKEE ATOMIC	ME	PWR	COMM	825	1972	2008
60	MCGUIRE 1	DUKE POWER COMPANY	NC	PWR	COMM	1180	1981	2021
61	MCGUIRE 2	DUKE POWER COMPANY	NC	PWR	COMM	1180	1983	2023
62	MILLSTONE 1	NORTHEAST UTILITY SVC CO.	CT	BWR	COMM	660	1970	2010
63	MILLSTONE 2	NORTHEAST UTILITY SVC CO.	CT	PWR	COMM	870	1975	2015
64	MILLSTONE 3	NORTHEAST UTILITY SVC CO.	CT	PWR	COMM	1150	1986	2025
65	MONTICELLO	NORTHERN STATES POWER CO.	MN	BWR	COMM	545	1971	2010
66	NINE MILE POINT 1	NIAGRA MOHAWK POWER CO.	NY	BWR	COMM	620	1969	2009
67	NINE MILE POINT 2	NIAGRA MOHAWK POWER CO.	NY	BWR	COMM	1080	1987	2026
68	NORTH ANNA 1	VIRGINIA POWER	VA	PWR	COMM	907	1978	2018
69	NORTH ANNA 2	VIRGINIA POWER	VA	PWR	COMM	907	1980	2020
70	OCONEE 1	DUKE POWER COMPANY	SC	PWR	COMM	887	1973	2013
71	OCONEE 2	DUKE POWER COMPANY	SC	PWR	COMM	887	1973	2013
72	OCONEE 3	DUKE POWER COMPANY	SC	PWR	COMM	886	1974	2014

Source: Spent Fuel Storage Requirements: 1994-2042 (DOE/RW-0431-Rev.1: June 1995)

Table 1-1 (Cont).

#	WASTE ORIGINS:	COMPANY:	STATE	WASTE TYPE	WASTE TYPE	DESIGN CAPAC (MWE)	UTIL STRTUP YEAR	UTIL SHUTD YEAR
73	OYSTER CREEK 1	GPU NUCLEAR CORP	NJ	BWR	COMM	650	1969	2009
74	PALISADES	CONSUMERS POWER CO.	MI	PWR	COMM	805	1971	2007
75	PALO VERDE 1	ARIZONA PUBLIC SERVICE CO.	AZ	PWR	COMM	1270	1985	2024
76	PALO VERDE 2	ARIZONA PUBLIC SERVICE CO.	AZ	PWR	COMM	1270	1986	2025
77	PALO VERDE 3	ARIZONA PUBLIC SERVICE CO.	AZ	PWR	COMM	1270	1987	2027
78	PEACHBOTTOM 2	PHILADELPHIA ELECTRIC CO.	PA	BWR	COMM	1065	1974	2008
79	PEACHBOTTOM 3	PHILADELPHIA ELECTRIC CO.	PA	BWR	COMM	1065	1974	2008
80	PERRY 1	CLEVELAND ELEC ILLUMINATING CO.	OH	BWR	COMM	1265	1986	2026
81	PILGRIM 1	BOSTON EDISON CO.	MA	BWR	COMM	655	1972	2012
82	POINT BEACH 1	WISCONSIN ELECTRIC POWER CO.	WI	PWR	COMM	497	1970	2010
83	POINT BEACH 2	WISCONSIN ELECTRIC POWER CO.	WI	PWR	COMM	497	1972	2013
84	PRAIRIE ISLAND 1	NORTHERN STATES POWER CO.	MN	PWR	COMM	530	1973	2013
85	PRAIRIE ISLAND 2	NORTHERN STATES POWER CO.	MN	PWR	COMM	530	1974	2014
86	QUAD CITIES 1	COMMONWEALTH EDISON CO.	IL	BWR	COMM	789	1972	2012
87	QUAD CITIES 2	COMMONWEALTH EDISON CO.	IL	BWR	COMM	789	1972	2012
88	RANCHO SECO 1	SACRAMENTO MUNICIPAL UTILITY DIST.	CA	PWR	COMM	918	1974	1989
89	RIVER BEND 1	GULF STATES UTILITIES CO.	LA	BWR	COMM	936	1985	2025
90	ROBINSON 2	CAROLINA POWER & LIGHT	SC	PWR	COMM	700	1970	2010
91	SALEM 1	PUBLIC SERVICE ELECTRIC & GAS CO	NJ	PWR	COMM	1115	1976	2016
92	SALEM 2	PUBLIC SERVICE ELECTRIC & GAS CO	NJ	PWR	COMM	1115	1981	2020
93	SAN ONOFRE 1	SOUTHERN CALIF EDISON	CA	PWR	COMM	436	1967	1992
94	SAN ONOFRE 2	SOUTHERN CALIF EDISON	CA	PWR	COMM	1070	1982	2013
95	SAN ONOFRE 3	SOUTHERN CALIF EDISON	CA	PWR	COMM	1080	1983	2013
96	SEABROOK 1	NORTH ATLANTIC ENERGY SERVICE	NH	PWR	COMM	1150	1990	2026
97	SEQUOYAH 1	TENNESSEE VALLEY AUTHORITY	TN	PWR	COMM	1148	1980	2020
98	SEQUOYAH 2	TENNESSEE VALLEY AUTHORITY	TN	PWR	COMM	1148	1981	2021
99	SHOREHAM	LONG ISLAND LIGHTING CO.	NY	BWR	COMM	849	1986	1987
100	SOUTH TEXAS 1	HOUSTON LIGHTING & POWER CO.	TX	PWR	COMM	1250	1988	2027
101	SOUTH TEXAS 2	HOUSTON LIGHTING & POWER CO.	TX	PWR	COMM	1250	1989	2028
102	ST LUCIE 1	FLORIDA POWER & LIGHTING CO.	FL	PWR	COMM	830	1976	2016
103	ST LUCIE 2	FLORIDA POWER & LIGHTING CO.	FL	PWR	COMM	804	1983	2023
104	SUMMER 1	SOUTH CAROLINA ELECTRIC & GAS	SC	PWR	COMM	900	1982	2022
105	SURRY 1	VIRGINIA POWER	VA	PWR	COMM	788	1972	2012
106	SURRY 2	VIRGINIA POWER	VA	PWR	COMM	788	1973	2013
107	SUSQUEHANNA 1	PENNSYLVANIA POWER & LIGHT	PA	BWR	COMM	1065	1982	2022
108	SUSQUEHANNA 2	PENNSYLVANIA POWER & LIGHT	PA	BWR	COMM	1065	1984	2024
109	THREE MILE ISLAND 1	GPU NUCLEAR CORP	PA	PWR	COMM	819	1974	2014
110	TROJAN	PORTLAND GENERAL ELECTRIC CO.	OR	PWR	COMM	1130	1975	1992
111	TURKEY POINT 3	FLORIDA POWER & LIGHTING CO.	FL	PWR	COMM	693	1972	2007
112	TURKEY POINT 4	FLORIDA POWER & LIGHTING CO.	FL	PWR	COMM	693	1973	2007
113	VERMONT YANKEE 1	VERMONT YANKEE NUCLEAR POWER	VT	BWR	COMM	514	1972	2012
114	VOGTLE 1	GEORGIA POWER CO.	GA	PWR	COMM	1069	1987	2027
115	VOGTLE 2	GEORGIA POWER CO.	GA	PWR	COMM	1069	1989	2029
116	WASHINGTON NUCLEAR 2	WASH PUBLIC POWER SUPPLY SYSTEM	WA	BWR	COMM	1100	1984	2023
117	WASHINGTON NUCLEAR 3	WASH PUBLIC POWER SUPPLY SYSTEM	WA	BWR	COMM	1250	????	????
118	WATERFORD 3	LOUISIANNA POWER & LIGHT	LA	PWR	COMM	1104	1985	2024
119	WATTS BAR 1	TENNESSEE VALLEY AUTHORITY	TN	PWR	COMM	1165	????	????
120	WATTS BAR 2	TENNESSEE VALLEY AUTHORITY	TN	PWR	COMM	1165	????	????
121	WOLF CREEK 1	WOLF CREEK NUCLEAR OPERATING CORP.	KS	PWR	COMM	1150	1985	2025
122	YANKEE-ROWE 1	YANKEE ATOMIC ELECTRIC CO.	MA	PWR	COMM	175	1960	1991
123	ZION 1	COMMONWEALTH EDISON CO.	IL	PWR	COMM	1085	1973	2013
124	ZION 2	COMMONWEALTH EDISON CO.	IL	PWR	COMM	1085	1973	2013
125	GENERAL ATOMICS	GENERAL ATOMICS	CA	RSH	DFNS	NA	????	????
126	HANFORD	DOE/HANFORD	WA	HLW	DFNS	NA	????	????
127	INEL	DOE/INEL	ID	HLW	DFNS	NA	????	????
128	SAVANNAH RIVER	DOE/SAVANNAH RIVER	SC	HLW	DFNS	NA	????	????
129	WEST VALLEY	DOE/WEST VALLEY	NY	HLW	DFNS	NA	????	????

Source: Spent Fuel Storage Requirements: 1994-2042 (DOE/RW-0431-Rev.1: June 1995)

Table 1-2. Storage Locations for Spent Nuclear Fuel and High-Level Waste

	STORAGE LOCATIONS:	WASTE TYPE	UTIL STRTUP YEAR	UTIL SHUTD YEAR	STRG CAPAC (ASSEMBLIES) LICEN	MAX	FULL CORE ASMB	NOTES:
1	ARKANSAS NUCLEAR 1	PWR	1974	2014	968	948	177	
2	ARKANSAS NUCLEAR 2	PWR	1978	2018	988	933	177	
3	ARKANSAS NUCLEAR DRY STRG	PWR	1995	2015	192	192	NA	VSC-24 under gnrl lic, starting 1995
4	BEAVER VALLEY 1	PWR	1976	2016	833	1621	157	
5	BEAVER VALLEY 2	PWR	1987	2027	1088	1088	157	
6	BELLEFONTE 1	PWR	????	????	1058	1058	205	
7	BELLEFONTE 2	PWR	????	????	1058	1058	205	
8	BIG ROCK 1	BWR	1962	2000	441	441	84	
9	BRAIDWOOD 1&2	PWR	1987	2027	2870	2834	193	
10	BROWNS FERRY 1-2	BWR	1973	2014	3471	6942	764	
11	BROWNS FERRY 3	BWR	1977	2016	3471	3471	764	
12	BRUNSWICK 1	BWR	1976	2016	1803	1767	560	
13	BRUNSWICK 1 BWR POOL	PWR	1976	2016	NA	160	NA	
14	BRUNSWICK 2	BWR	1974	2014	1839	1767	560	
15	BRUNSWICK 2 BWR POOL	PWR	1974	2014	NA	144	NA	
16	BYRON 1&2	PWR	1985	2026	2870	2824	193	
17	CALLAWAY 1	PWR	1984	2024	1340	1340	193	
18	CALVERT CLIFFS 1-2	PWR	1975	2016	1830	1778	217	
19	CALVERT DRY STORAGE	PWR	1991	2011	1152	1152	NA	NUHOMS-24 under 1992 site specific lic
20	CATAWBA 1	PWR	1985	2024	1419	2615	193	
21	CATAWBA 2	PWR	1986	2026	1418	2615	193	
22	CLINTON 1	BWR	1987	2026	2512	2512	624	
23	COMANCHE PEAK 1-2	PWR	1990	2030	1693	1289	193	
24	COOK 1&2	PWR	1975	2017	2050	3613	193	
25	COOPER STATION	BWR	1974	2014	2366	2366	548	
26	CRYSTAL RIVER 3	PWR	1977	2016	1357	1357	177	
27	DAVIS-BESSE 1	PWR	1977	2017	735	720	177	
28	DAVIS-BESSE DRY STRG	PWR	1995	2015	192	192	NA	NUHOMS-24 under gnrl lic, starting 1995
29	DIABLO CANYON 1	PWR	1984	2010	1324	1324	193	
30	DIABLO CANYON 2	PWR	1985	2010	1324	1317	193	
31	DRESDEN 1	BWR	1960	1978	720	720	464	
32	DRESDEN 2	BWR	1970	2006	3537	3537	724	
33	DRESDEN 3	BWR	1971	2011	3537	3537	724	
34	DUANE ARNOLD	BWR	1974	2014	2050	1898	368	
35	ENRICO FERMI 2	BWR	1985	2025	2383	2383	764	
36	FARLEY 1	PWR	1977	2017	1407	1407	157	
37	FARLEY 2	PWR	1981	2021	1407	1407	157	
38	FITZPATRICK	BWR	1975	2014	2797	2797	560	
39	FORT CALHOUN	PWR	1973	2008	729	1083	133	
40	FORT ST VRAIN	HTG	1979	1989	1482	0	0	
41	FORT ST VRAIN DRY STRG	HTG	1991	2011	1482	1482	NA	Foster Wheeler MVDS under 1991 site specific lic
42	GINNA	PWR	1969	2009	1016	1083	121	
43	GRAND GULF 1	BWR	1984	2022	2324	3872	800	
44	HADDAM NECK	PWR	1967	2007	1172	1167	157	
45	HARRIS 1-2	PWR	1987	2026	4184	1128	157	
46	HARRIS 1-2 BWR POOL	BWR	1987	2026	NA	1573	NA	
47	HATCH 1-2	BWR	1974	2018	3181	5830	560	
48	HOPE CREEK	BWR	1986	2026	4006	3998	764	
49	HUMBOLDT BAY	BWR	1963	1976	486	485	184	
50	INDIAN POINT 1	PWR	1962	1980	756	756	120	
51	INDIAN POINT 2	PWR	1973	2013	1374	1374	193	
52	INDIAN POINT 3	PWR	1976	2015	1345	1340	193	
53	KEWAUNEE	PWR	1974	2013	990	990	121	
54	LACROSSE	BWR	1968	1987	440	440	72	
55	LASALLE 1-2	BWR	1982	2023	5153	7780	764	
56	LIMERICK 1-2	BWR	1985	2029	2040	6798	764	
57	MAINE YANKEE	PWR	1972	2008	1476	1464	217	
58	MCGUIRE 1	PWR	1981	2021	1463	1581	193	
59	MCGUIRE 2	PWR	1983	2023	1463	1460	193	
60	MILLSTONE 1	BWR	1970	2010	3229	3229	580	
61	MILLSTONE 2	PWR	1975	2015	1072	1299	217	
62	MILLSTONE 3	PWR	1986	2025	756	756	193	
63	MONTICELLO	BWR	1971	2010	2237	2229	484	
64	NINE MILE POINT 1	BWR	1969	2009	2776	2560	532	
65	NINE MILE POINT 2	BWR	1987	2026	4049	2528	764	
66	NORTH ANNA 1&2	PWR	1978	2020	1737	1677	157	
67	NORTH ANNA DRY STRG	PWR	1998	2018	256	256	NA	TN-32 under 1998 site specific lic
68	OCONEE 1&2	PWR	1973	2013	1312	1311	177	
69	OCONEE 3	PWR	1974	2014	825	818	177	
70	OCONEE DRY STORAGE	PWR	1990	2010	960	960	NA	NUHOMS-24 under 1990 site specific lic
71	OYSTER CREEK 1	BWR	1969	2009	2600	2600	560	
72	OYSTER CREEK DRY STRG	BWR	1996	2016	416	416	NA	NUHOMS-52 under gnrl lic, starting 1996

Table 1-2 (Cont).

	STORAGE LOCATIONS:	WASTE TYPE	UTIL STRTUP YEAR	UTIL SHUTD YEAR	STRG CAPAC (ASSEMBLIES) LICEN	MAX	FULL CORE ASMB	NOTES:
73	PALISADES	PWR	1971	2007	892	888	204	
74	PALISADES DRY STRG	PWR	1993	2013	48	48	NA	NUHOMS-24 under gnrl lic, starting 1996
75	PALO VERDE 1	PWR	1985	2024	665	1323	241	
76	PALO VERDE 2	PWR	1986	2025	665	1323	241	
77	PALO VERDE 3	PWR	1987	2027	665	1322	241	
78	PEACHBOTTOM 2	BWR	1974	2008	3819	3819	764	
79	PEACHBOTTOM 3	BWR	1974	2008	3819	3814	764	
80	PERRY 1	BWR	1986	2026	4020	4020	748	
81	PILGRIM 1	BWR	1972	2012	2320	2875	580	
82	POINT BEACH 1&2	PWR	1970	2013	1502	1500	121	
83	POINT BEACH DRY STRG	PWR	1995	2015	192	192	NA	VSC-24 under gnrl lic, starting 1995
84	PRAIRIE ISLAND 1&2	PWR	1973	2014	1386	1378	121	
85	PRAIRIE ISLAND DRY STRG	PWR	1993	2013	320	320	NA	TN-40 under 1993 site specific lic
86	QUAD CITIES 1-2	BWR	1972	2012	7554	7533	724	
87	RANCHO SECO 1	PWR	1974	1989	1080	1080	177	
88	RANCHO SECO DRY STRG	PWR	1996	2016	561	561	NA	NUHOMS-MP187 under 1996 site specific lic
89	RIVER BEND 1	BWR	1985	2025	2680	3172	624	
90	ROBINSON 2	PWR	1970	2010	544	537	157	
91	ROBINSON DRY STRG	PWR	1986	2006	56	56	NA	NUHOMS-07 under 1986 site specific lic
92	SALEM 1	PWR	1976	2016	1170	1117	193	
93	SALEM 2	PWR	1981	2020	1170	1139	193	
94	SAN ONOFRE 1	PWR	1967	1992	216	216	157	
95	SAN ONOFRE 2	PWR	1982	2013	1542	1542	217	
96	SAN ONOFRE 3	PWR	1983	2013	1542	1542	0	
97	SEABROOK 1	PWR	1990	2026	1236	1236	193	
98	SEQUOYAH 1&2	PWR	1980	2021	1386	2091	193	
99	SHOREHAM	BWR	1986	1987	2436	2685	560	
100	SOUTH TEXAS 1	PWR	1988	2027	1969	1958	193	
101	SOUTH TEXAS 2	PWR	1989	2028	1969	1958	193	
102	ST LUCIE 1	PWR	1976	2016	1706	1705	217	
103	ST LUCIE 2	PWR	1983	2023	1584	1076	217	
104	SUMMER 1	PWR	1982	2022	1276	1276	157	
105	SURRY 1&2	PWR	1972	2013	1044	1044	157	
106	SURRY DRY STORAGE	PWR	1986	2006	533	533	NA	CASTOR-32 (& other) under 1986 site spec lic
107	SUSQUEHANNA 1-2	BWR	1982	2024	2840	5680	764	
108	SUSQUEHANNA DRY STRG	BWR	1997	2017	416	416	NA	NUHOMS-52 under gnrl lic, starting 1997
109	THREE MILE ISLAND 1	PWR	1974	2014	752	1284	177	
110	TROJAN	PWR	1975	1992	1408	1395	193	
111	TURKEY POINT 3	PWR	1972	2007	1404	1376	157	
112	TURKEY POINT 4	PWR	1973	2007	1404	1376	0	
113	VERMONT YANKEE 1	BWR	1972	2012	2870	2860	368	
114	VOGTLE 1-2	PWR	1987	2029	2386	2283	193	
115	WASHINGTON NUCLEAR 2	BWR	1984	2023	2658	2654	764	
116	WATERFORD 3	PWR	1985	2024	1088	1070	217	
117	WATTS BAR 1&2	PWR	????	????	1312	1294	193	
118	WOLF CREEK 1	PWR	1985	2025	1340	1327	193	
119	YANKEE-ROWE 1	PWR	1960	1991	721	721	76	
120	ZION 1&2	PWR	1973	2013	2112	2929	193	
121	HANFORD SNF STRG	PWR	????	????	????	????	NA	
122	HANFORD SNF STRG	BWR	????	????	????	????	NA	
123	INEL SNF STRG	PWR	????	????	????	????	NA	
124	INEL SNF STRG	BWR	????	????	????	????	NA	
125	INEL SNF STRG	HTG	????	????	????	????	NA	
126	SAVANNAH RIVER SNF STRG	PWR	????	????	????	????	NA	
127	SAVANNAH RIVER SNF STRG	BWR	????	????	????	????	NA	
128	WEST VALLEY SNF STRG	PWR	????	????	????	????	NA	
129	WEST VALLEY SNF STRG	BWR	????	????	????	????	NA	
130	MORRIS OPERATION	PWR	????	2002	????	380	NA	
131	MORRIS OPERATION	BWR	????	2002	????	2928	NA	
132	GENERAL ATOMICS	RSH	????	????	????	????	NA	
	TOTAL							

Source: Spent Fuel Storage Requirements: 1994-2042 (DOE/RL-0431.... June 1995
Spent Nuclear Fuel Discharges From US Reactors: 1994 (SR/CNEAF/96-01..... Feb 1996)
1-2: Joined pools; 1&2: Shared pools.... later shutdown reactor date applies
Max pool capacities: generally from SFSR; SNFD as noted
Dry storage capacities: generally from SFSR; SNFD or PIC as noted

Table 1-3. Spent Nuclear Fuel and High-Level Waste Shipment Sites

SHIPMENT SITE:	WASTE TYPE
1 ARKANSAS NUCLEAR	PWR
2 BEAVER VALLEY	PWR
3 BELLEFONTE	PWR
4 BIG ROCK	BWR
5 BRAIDWOOD	PWR
6 BROWNS FERRY	BWR
7 BRUNSWICK	BWR
	PWR
8 BYRON	PWR
9 CALLAWAY	PWR
10 CALVERT CLIFFS	PWR
11 CATAWBA	PWR
12 CLINTON	BWR
13 COMANCHE PEAK	PWR
14 COOK	PWR
15 COOPER STATION	BWR
16 CRYSTAL RIVER	PWR
17 DAVIS-BESSE	PWR
18 DIABLO CANYON	PWR
19 DRESDEN	BWR
20 DUANE ARNOLD	BWR
21 ENRICO FERMI	BWR
22 FARLEY	PWR
23 FITZPATRICK	BWR
24 FORT CALHOUN	PWR
25 FORT ST VRAIN	HTG
26 GINNA	PWR
27 GRAND GULF	BWR
28 HADDAM NECK	PWR
29 HARRIS	PWR
	BWR
30 HATCH	BWR
31 HOPE CREEK	BWR
32 HUMBOLDT BAY	BWR
33 INDIAN POINT	PWR
34 KEWAUNEE	PWR
35 LACROSSE	BWR
36 LASALLE	BWR
37 LIMERICK	BWR
38 MAINE YANKEE	PWR
39 MCGUIRE	PWR
40 MILLSTONE	BWR
41 MONTICELLO	BWR
42 NINE MILE POINT	BWR
43 NORTH ANNA	PWR
43 NORTH ANNA	PWR
44 OCONEE	PWR
45 OYSTER CREEK	BWR
46 PALISADES	PWR
47 PALO VERDE	PWR

FUEL STRG LOCATIONS	WASTE TYPE
48 PEACHBOTTOM	BWR
49 PERRY	BWR
50 PILGRIM	BWR
51 POINT BEACH	PWR
52 PRAIRIE ISLAND	PWR
53 QUAD CITIES	BWR
54 RANCHO SECO	PWR
55 RIVER BEND	BWR
56 ROBINSON	PWR
57 SALEM	PWR
58 SAN ONOFRE	PWR
59 SEABROOK	PWR
60 SEQUOYAH	PWR
61 SHOREHAM	BWR
62 SOUTH TEXAS	PWR
63 ST LUCIE	PWR
64 SUMMER	PWR
65 SURRY	PWR
67 SUSQUEHANNA	BWR
68 THREE MILE ISLAND	PWR
69 TROJAN	PWR
70 TURKEY POINT	PWR
71 VERMONT YANKEE	BWR
72 VOGTLE	PWR
73 WASH NUCLEAR	BWR
74 WATTS BAR	PWR
75 WATERFORD	PWR
76 WOLF CREEK	PWR
77 YANKEE-ROWE	PWR
78 ZION	PWR
79 HANFORD	PWR
	BWR
	HLW
80 INEL	PWR
	BWR
	HTG
	HLW
	NRF
81 SAVANNAH	PWR
	BWR
	HLW
	FRF
82 WEST VALLEY	BWR
	PWR
	HLW
83 MORRIS	BWR
	PWR
84 GENERAL ATOMICS	RSH
	MSC

Waste Types:

BWR: Assemblies from boiling water reactors
PWR: Assemblies from pressurized water reactors
HTG: Assemblies from high-temp gas reactors
MSC: Miscellaneous spent fuel discharges thru Nov 1994 (@GA)
RSH: Spent fuel for research, thru Nov 1994 (@GA)
NRF: Naval reactor fuel
FRF: Foreign research fuel
HLW: High-level defense waste (not spent fuel)

2. THE INVENTORY OF SPENT NUCLEAR FUEL AND HIGH-LEVEL WASTE

The radioactive wastes which require geologic disposal and which could be shipped to a centralized storage facility at the Nevada Test Site (Area 25) to await permanent disposal are in three broad categories: SNF from commercial power plants, HLW from the nation's defense complex, and other wastes requiring geologic disposal. It is convenient to consider the current and projected inventory of these wastes with reference to their key relevant information sources. This, however, introduces some minor anomalies. For example, a portion of research and miscellaneous spent fuel is included in the current inventory of commercial SNF, since it is included in the key information source (prioritized spent fuel discharges) for this category. Also, the consideration of other wastes requires special attention to avoid double-counting.

2.1 Spent Nuclear Fuel from Commercial Plants

The Current SNF Inventory

Through November 1994, 30,044 metric tons of SNF had been permanently discharged from U.S. reactors, and had received priority ranking for acceptance by DOE (see Table 2-1). Of the November 1994 total,

- About 10,809 MTU (36.0 percent) was in 59,400 assemblies discharged from 41 commercial boiling water reactors. The average BWR assembly weighs .182 tons or 364 pounds.
- About 19,149 MTU (63.7 percent) was in 44,600 assemblies discharged from 78 commercial pressurized water reactors. The average PWR assembly weighs .429 tons or 869 pounds.
- About 86 MTU (0.3 percent) was discharges from the high-temperature gas reactor at Fort St. Vrain, Colorado, or discharges of research or miscellaneous spent fuel.

Ranked spent fuel discharges do not include naval reactor fuel, foreign research fuel, or spent fuel discharged from defense reactors. Nor does it include the HLW that have accumulated at defense sites.

The Future SNF Inventory

DOE has projected annual spent fuel discharges from 1994 through 2042 at commercial reactors,[4] under a case which assumes no-new-reactor orders and operations through the current NRC license term (with no early shut downs and no license extensions). The projected discharges include 56,655 MTU in 19,900 BWR and 36,800 PWR assemblies.

In this assessment, 1994 discharges are the "actuals" reported in DOE's 1995 Acceptance Priority Ranking through November 28, 1994. The differences between the actuals for 1994 and DOE's 1994 projections are included in the projected discharges for 1995, so that the projections for 1994 through 2042 are consistent with DOE's forecast for the no-new-orders, NRC license term case.

DOE's forecast is presented by the reactor from which the assemblies are discharged. This assessment identifies the pool location (separate, shared, or joined) to which the fuel would be discharged, but does not attempt to project future transfers of spent fuel to onsite dry storage facilities or to pools at other sites owned by the same utility or others.

The Total SNF Inventory

Combining projected spent fuel discharges with those through November 28, 1994, the total inventory includes 86,699 MTU in 30,700 BWR and 55,900 PWR assemblies. This total, however, does not include projections of spent fuel from research reactors, or projected naval reactor fuel, foreign research fuel, or HLW from defense facilities.

Alternative Inventory Projections

Alternative projections of waste requiring geologic disposal could be considered in alternative scenarios. Some of the contingencies that might be considered in alternative scenarios are briefly discussed below:

- **Reactors licensed for startup after 1993.**

  DOE's forecast for the no-new-orders, NRC license term case includes discharges for five reactors scheduled for startup after 1993, the base year for the DOE forecast:

  — Bellefonte 1, projected to discharge 2,193 PWR assemblies and 913 MTU between 2000 and 2039.

  — Bellefonte 2, projected to discharge 2,076 PWR assemblies and 864 MTU between 2003 and 2042.

  — Comanche Peak 2, projected to discharge 2,081 PWR assemblies and 856 MTU between 1994 and 2033.

  — Watts Bar 1, projected to discharge 1,725 PWR assemblies and 800 MTU between 1996 and 2035.

  — Watts Bar 2, projected to discharge 1,648 PWR assemblies and 763 MTU between 1998 and 2037.

  It is possible, even likely, that the above plants, though licensed, will never operate. In this case, projected discharges would be reduced by 9,723 PWR assemblies or 4,196 MTU, about 17.4 percent of the total inventory of 55,900 PWR assemblies in the no-new-orders case, and about 4.8 percent of total projected MTU.

- **Reactors shut down before their NRC license term**

  The economics of generating nuclear power in increasingly competitive electric power markets, as well as the cost of dealing with aging nuclear reactors[6] and/or problems in providing onsite storage capacity, could persuade utilities to shut down some reactors before their NRC license term. The transportation effects of such decisions, which would reduce the revenue base for the nuclear waste fund, and complicate the financing of plant decommissioning, could be considered in an alternative inventory scenario.

- **Reactor license extensions**

  Extension of operating licenses beyond the standard 40-year term has been periodically considered by the NRC and utilities. Extensions would be contingent on the solution of problems associated with aging reactors and onsite storage, but could augment the nuclear waste fund as well as funds for decommissioning. The transportation effects of possible license extensions could be considered in an alternative inventory scenario.

2.2 High-Level Wastes from the Defense Complex

High-level waste is generated by the chemical reprocessing of spent research and production reactor fuel, irradiated targets and naval propulsion fuel. It exists in a variety of physical or chemical forms, all of which must be stored behind heavy shielding and usually in underground tanks or bins. Since DOE decided in 1992 to phase out the domestic reprocessing of irradiated nuclear fuel for the recovery of enriched uranium or plutonium, little additional generation of HLW is expected.

Current DOE plans are to immobilize HLW through a vitrification process, and to package it in canisters for storage at the four sites where it was produced (Hanford, INEL, Savannah River, West Valley) and for shipment to the geologic repository for disposal. The canisters are expected to be about 2 feet in diameter and from 10 to 15 feet in length. However, since pretreatment and waste minimization processes at the INEL and Hanford sites have not yet been finalized, the dimensions and number of canisters to be produced from those sites is less certain than at Savannah River and West Valley.

DOE's Integrated Data Base Report[5] (the source for the above summary) provides a projection of the number of canisters of HLW expected to be produced at each of the four sites, noting that "projected inventories. . .(are) based on certain assumptions, and therefore should be considered only as current best estimates." An alternative projection, with substantially higher production estimates for Hanford and INEL, is provided in DOE's Waste Management Programmatic EIS.[7] This assessment combines the canister production rate from the first source with the canister production totals from the second (Figure 2-1). It is assumed that the canisters would be stored at the sites where they are produced, awaiting shipment to a centralized storage or permanent disposal facility.

2.3 Other Wastes Requiring Geologic Disposal

A variety of other radioactive wastes require permanent geologic disposal. Under DOE waste management plans or DOE agreements with states such as Idaho, these wastes could be shipped to a centralized above-ground facility for storage while awaiting permanent disposal. A recent DOE document[8] provides the best available information on the inventory of such wastes, which could total about 2,700 MTU, about 9.0 percent of the commercial spent fuel discharged through November 1994. This section briefly discusses the categories and projected inventory of "other wastes requiring geologic disposal," but the schedule, packages, and routes by which they would be shipped to Nevada are not included in this assessment.

- **Naval Reactor Fuel**

  Spent fuel from the power plants of the Navy's submarines and aircraft carriers is being shipped to INEL for storage, but, under an October 1995 agreement with the State of Idaho, must be removed from the state by 2035. The current inventory of such fuel at INEL is about 10.23 MTU, and an additional 55 tons may be accumulated.

- **Defense Production Reactor Fuel**

  About 2,100 MTU of SNF has been generated at Hanford's weapons production reactors (reactors N and K) and about 150 MTU at Savannah River. Prior to DOE's 1992 decision, this spent fuel would have been reprocessed—producing enriched uranium or plutonium as well as HLW. Under the 1992 decision, however, it will be packaged for shipment to a permanent geologic repository, perhaps via a centralized above-ground storage facility.

- **Spent Fuel from Research Reactors: DOE**

  Spent fuel has been discharged from research reactors at INEL (about 263.9 MTU), Savannah River (about 56.3 MTU), Hanford (about 32.4 MTU), Oak Ridge (about 1.8 MTU), and elsewhere (Battelle, Sandia, Los Alamos, Argonne-East: about 2.3 MTU). This material, which is in assemblies generally about one-quarter of the size of BWR assemblies will require geologic disposal.

- **Spent Fuel from Research Reactors: Non-DOE**

  About 5.5 MTU from non-DOE research reactors (about 90 percent from research reactors at universities, about 10 percent from research reactors at other federal agencies or commercial sites) will require geologic disposal. This total does not include the 3.2 MTU of spent fuel from the General Atomics research reactor near San Diego, which has acceptance priority under the standard contract.

- **Spent Fuel from Research Reactors: Foreign**

  About 21.7 MTU of spent fuel provided for research in foreign countries is being returned to the U.S. (arriving at various ports of entry) for management and disposal at a geologic repository. The fuel may be shipped for storage at DOE facilities (e.g., Hanford, INEL, Savannah River) pending subsequent transportation to a centralized storage or disposal site.

Table 2-1. Spent Nuclear Fuel: Discharges, Assemblies, MTIHM
Current Inventory: Discharges Through November 28, 1994
Future Additions: Discharges 1995 through 2042

	DISCHG	ASSMBL	MTU	MTU/A	LBS/A	A/DSCHG	MTU/D
CURRENT:							
BWR	411	59418	10809	0.182	364	145	26
PWR	843	44602	19149	0.429	859	53	23
HTG	6	2208	24	0.011	22	368	4
RSC	32	72	3	0.044	89	2	0
MSC	3	0	59	NA	0	0	NA
SUM	1295	106300	30044	0.283	565	82	23
FUTURE:							
BWR	1872	110257	19873	0.180	360	59	11
PWR	3552	84915	36782	0.433	866	24	10
HTG	0	0	0	NA	0	NA	NA
RSC	0	0	0	NA	0	NA	NA
MSC	0	0	0	NA	0	NA	NA
SUM	5424	195172	56655	0.290	581	36	10
TOTAL:							
BWR	2283	169675	30682	0.181	362	74	13
PWR	4395	129517	55931	0.432	864	29	13
HTG	6	2208	24	0.011	22	368	4
RSC	32	72	3	0.044	89	2	0
MSC	3	0	59	NA	0	0	NA
SUM	6719	301472	86699	0.288	575	45	13

		DISCHG	ASSMBL	MTU	MTU/A	LBS/A	A/DSCHG	MTU/D
BWR:	Current	411	59418	10809	0.182	364	145	26
	Future	1872	110257	19873	0.180	360	59	11
	Total	2283	169675	30682	0.181	362	74	13
PWR:	Current	843	44602	19149	0.429	859	53	23
	Future	3552	84915	36782	0.433	866	24	10
	Total	4395	129517	55931	0.432	864	29	13
HTG:	Current	6	2208	24	0.011	22	368	4
	Future	0	0	0	NA	0	NA	NA
	Total	6	2208	24	0.011	22	368	4
RSC:	Current	32	72	3	0.044	89	2	0
	Future	0	0	0	NA	0	NA	NA
	Total	32	72	3	0.044	89	2	0
MSC:	Current	3	0	59	NA	0	0	NA
	Future	0	0	0	NA	0	NA	NA
	Total	3	0	59	NA	0	0	NA
SUM:	Current	1295	106300	30044	0.283	565	82	23
	Future	5424	195172	56655	0.290	581	36	10
	Total	6719	301472	86699	0.288	575	45	13

Source: DOE Acceptance Priority Ranking: Nov 28, 1994
Spent Fuel Storage Req: 1994-2042 (Tables B.1a & 1b),
via PIC: DISCHG, ACCPT94V, ACCPT95X

Figure 2-1a. Cumulative Projected Production of HLW Canisters at West Valley, Savannah River, Hanford, and Idaho National Engineering Lab

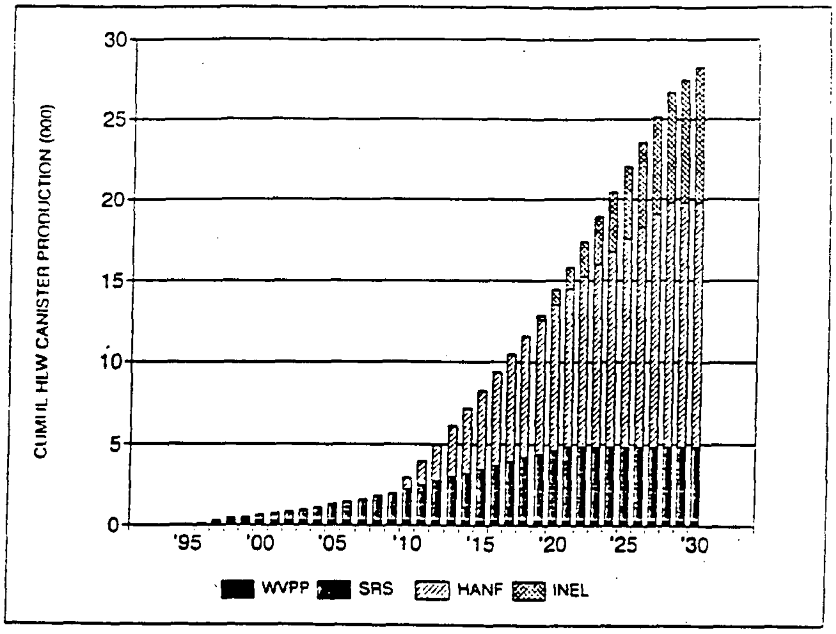
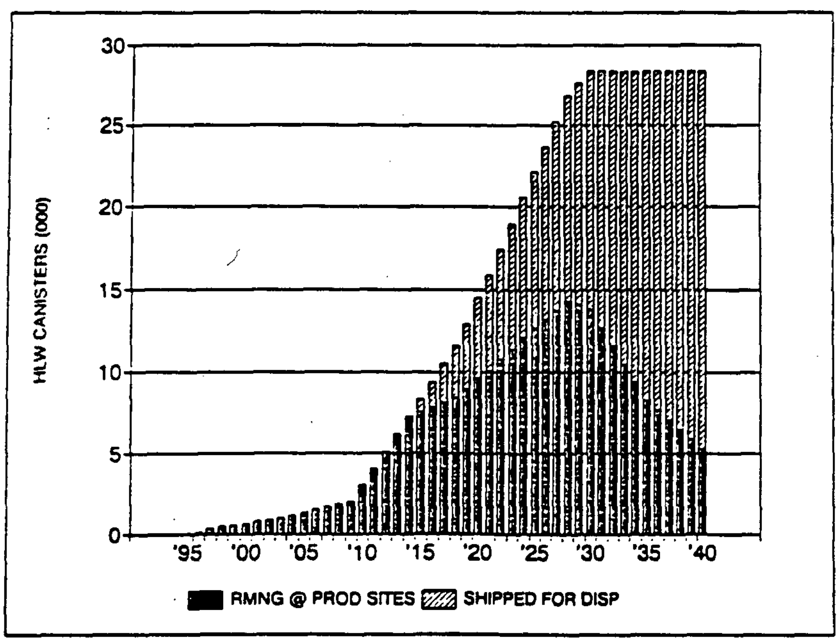


Figure. 2-1b. Cumulative Projected HLW Canisters—Shipped and Remaining at Production Sites



3. ACCEPTANCE STARTUP AND RATE

When the federal government is obligated to take title to SNF, and the annual rate at which it must pick up waste for transportation to and management at a federally-licensed facility are matters of current legal and legislative controversy:

Acceptance Startup Year

DOE has argued that acceptance would begin when a federally-licensed facility is available.[9] Since current legislation does not authorize construction of a centralized above-ground storage facility in Nevada, and since the suitability of Yucca Mountain as a permanent disposal site is uncertain, a date at which acceptance would begin cannot be specified.

Industry, on the other hand, has argued that the standard contract established by the NWPA requires the federal government to begin acceptance in 1998, in return for payments to the nuclear waste fund of 1 mill per kilowatt hour of nuclear generated electricity.[10]

This assessment does not specify the acceptance start year; acceptance begins in "year 1" and extends through "year 31". Assuming a 1998 startup year, and the acceptance rate specified in proposed legislation (see below), at least 84,100 MTU of SNF would be accepted by the end of the year 2027 (the 30th acceptance year)—reducing spent fuel in temporary storage to about 850 MTU. This spent fuel, plus about 1,610 MTU generated between 2027 and 2042 (under DOE's no-new-orders, NRC license term forecast[4]) is included in the "31st acceptance year," though in fact the fuel would be accepted in small quantities over a 22-year period between 2028 and 2050.

Changing the startup year to 2003, 84,100 MTU of SNF would not be accepted until the end of the year 2032 (the 30th acceptance year)—at which point the SNF in temporary storage would be about 1,715 MTU. This spent fuel, plus about 750 MTU generated between 2032 and 2042, is included in the "31st acceptance year", though in fact the fuel would be accepted in small quantities over a 17-year period between 2033 and 2050.

Acceptance Rate

DOE has suggested[11] that spent fuel would be accepted at a rate of 400 MTU in the first acceptance year, 600 MTU in the second, and 900 MTU in years three through ten. Only after year 10, other DOE reports[12] suggest, would acceptance and pick up increase to 3,000 MTU annually.

By contrast, proposed legislation would require acceptance of at least 1,200 MTU in the first and second acceptance years, 2,000 MTU in the third and fourth acceptance years, 2,700 MTU in the fifth acceptance year, and 3,000 MTU in the sixth and subsequent acceptance years.

This assessment uses the acceptance rate required by proposed legislation. The implication is that at least 9,100 MTU would be accepted for pickup and transport to a centralized storage facility over the first five acceptance years, and 15,000 MTU over each subsequent five-year period. Compared with acceptance rates implied by DOE reports, proposed legislation (e.g., S-1936) would increase pick up by

5,400 MTU over the first five years, by 10,500 MTU over the second five years, and by 3,000 MTU over the third five years.

SNF Acceptance and Pick Up (MTU)

	DOE	S-1936	Difference
Years 1 - 5	3,700	9,100	5,400
Years 6 - 10	4,500	15,000	10,500
Years 11 - 15	12,000	15,000	3,000
Years 16 - 20	15,000	15,000	0
Years 1 - 15	20,200	39,100	18,900

Shipment of High-Level Wastes

This assessment assumes that the start date for shipment of canisters of vitrified high-level waste from DOE defense sites in year 15—that is, 15 years after the start date for spent fuel shipments, or 2015 assuming that spent fuel shipments begin in the year 2000. Once begun, this assessment assumes that HLW canisters would be shipped at an annual rate of 800 in the first five years, 900 in the second five, and 600 in subsequent years. At these rates, shipments would continue through 2049, roughly 20 years beyond the conclusion of SNF shipments.

Would a permanent geologic repository be available in year 15 (i.e., in 2015 if SNF shipments begin in the year 2000, in 2025 if SNF shipments begin in 2010), and could or would HLW be shipped to Nevada for centralized above-ground storage while awaiting permanent disposal? The answer is uncertain. The October 1995 settlement agreement between the State of Idaho and the DOE suggests (Section C3) that all HLW as well as naval reactor fuel and foreign research reactor fuel must be moved out of Idaho (i.e., to Nevada) by January 2035, and a possible interpretation of proposed legislation would allow shipment of HLW for centralized above-ground storage if a geologic repository is unavailable. As mentioned, this assessment assumes HLW shipments begin year 15 after the start of SNF shipments, whether the Nevada destination is a centralized storage facility or a permanent repository.

4. ACCEPTANCE PRIORITY

Spent Fuel Discharges and Prioritization

The first spent fuel permanently discharged from a commercial nuclear plant occurred on June 21, 1968 and included five assemblies from the Big Rock Point boiling water reactor in northern Michigan. These assemblies, plus 80 others discharged from Big Rock in the late 1960s and early 1970s, are now stored at West Valley, in western New York State. The next spent fuel discharge from a commercial nuclear plant occurred on September 6, 1969 and included 94 assemblies from the Dresden 1 boiling water reactor in northeastern Illinois. These assemblies have been transferred for storage in the Dresden 2 and 3 spent fuel pools. The most recent spent fuel discharge in the current listing occurred on November 28, 1994 and included 204 assemblies from the Fitzpatrick boiling water reactor, north of Syracuse, New York, near the southeast corner of Lake Ontario.

Overall, there have been 1,108 discharges from commercial nuclear reactors through November 28, 1994—each of which is ranked for acceptance by year, month and day, and many of which have been subsequently separated into portions stored at various temporary locations. Assuming that DOE accepts "oldest-fuel-first," spent fuel would be picked up in the order in which it was discharged. This is the assumption in this assessment, though utilities are free to apply priorities to other fuel in their system, or to sell or auction priorities to other utilities. Also, proposed legislation might give priority to fuel at shut down reactors, which might help certain utilities to shut down their spent fuel pools earlier, and avoid the significant expense of continued pool operations at shut-down plants.

The Use of Spent Fuel Priorities

Though difficult to predict, some examples illustrate how utilities might use the priorities of spent fuel in their system:

- Pacific Gas and Electric has 29.2 MTU in BWR assemblies stored at Humboldt Bay, whose reactor was shut down in 1976, and 427.7 MTU in PWR assemblies stored at Diablo Canyon, whose reactors are scheduled for shut down in 2008 and 2010. The spent fuel at Humboldt Bay was discharged in the early and mid-1970's, giving it priority for pickup in the first two acceptance years, while that at Diablo Canyon was discharged after 1985, giving it priority for pickup in years 7 to 12.

  Pacific Gas and Electric could use the priority of its fuel at Humboldt Bay to empty and shut down the Humboldt Bay pool, thus avoiding the expense of its continued operation. Or, it could use the priority of its fuel at Humboldt Bay to ship from Diablo Canyon, thus providing additional pool capacity at the still-operating Diablo Canyon plants.

- Consumers Power Company has 44.7 MTU in BWR assemblies stored at Big Rock (whose reactor is scheduled for shut down in the year 2000), and 316.8 MTU in PWR assemblies stored at Palisades (whose reactor is scheduled for shut down in 2007). While Consumers Power has 181.1 MTU of spent fuel with rankings which qualify for pickup in the first five acceptance years, almost all (91.9 percent) is stored at Palisades rather than at the Big Rock spent fuel pool.

Consumers Power could choose to use the priority of fuel in its system to empty the Big Rock pool after the Big Rock reactor shuts down in 2000, thus eliminating the expense of its continued operation. The Palisades dry storage facility would be required to enable its reactor to continue operation through its NRC license term.

- Northern States Power has 198.7 MTU in BWR assemblies stored at Morris, 147.5 MTU in BWR assemblies stored at Monticello (whose plant is scheduled for shut down in 2010), and 502.0 MTU stored at Prairie Island, whose plants are scheduled for shut down in 2013 and 2014, but which has very limited onsite storage capacity (wet or dry) to support continued plant operations. While Northern States Power has 191.8 MTU of spent fuel with rankings which qualify for pickup in the first three acceptance years, over half is stored at Morris (46.9 percent) or Monticello (5.0 percent) rather than at Prairie Island.

  Northern States could choose to use the priority of its spent fuel at Morris and Monticello to ship from Prairie Island, making additional storage capacity available there. While the capacity limitations at the Monticello spent fuel pool are much less severe than those at Prairie Island, the dimensions of the pool at Monticello (which was designed for BWR assemblies) preclude the transfer of PWR assemblies from Prairie Island. With confidence regarding an acceptance/shipment start date, Northern States might choose to purchase priority positions from one or more utilities with more sufficient onsite storage capacity.

5. SHIPMENT GROUPS

Spent Fuel Forms and Ages

Spent fuel discharged from boiling water reactors is in 52 different types of assemblies.[13] As of July 1, 1996, 8.6 percent of the MTU discharged from boiling water reactors is over 20 years old, 41.4 percent is between 10 and 20 years old, and 50.0 percent is less than 10 years old.

Spent fuel discharged from pressurized water reactors is in 54 different types of assemblies. As of July 1, 1996, 5.3 percent of the MTU discharged from boiling water reactors is over 20 years old, 37.4 percent is between 10 and 20 years old, and 57.3 percent is less than 10 years old.

Under an oldest-fuel-first acceptance prioritization, spent fuel which is over 20 years old on July 1, 1996 would be picked up in the first and second acceptance years. Spent fuel which is between 10 and 20 years old would be picked up in the second through seventh acceptance years, while fuel less than 10 years old would be picked up in the seventh through twelfth acceptance years. If acceptance begins in January 1998, the 40 PWR assemblies discharged from the Trojan plant in May 1986 would be picked up in 2005—meaning that Portland General Electric will have stored these assemblies in an operating spent fuel pool for 19 years, and for 13 years after the Trojan plant shut down in 1992.

Criteria for Cask Loading

How would the discharges at various storage locations be grouped for loading into transportation casks for shipment in a particular acceptance year?

- Would discharges whose priority ranking places them in different acceptance years be mixed in the same transportation cask? Under an oldest-fuel-first acceptance prioritization, the assumption in this assessment is "no."

- Would BWR or PWR discharges of different assembly types be mixed in the same transportation cask? The assumption in this assessment is "yes, as necessary." Thus, for example, the 335 assemblies at Big Rock, which include seven BWR assembly types fabricated by three companies (General Electric, Siemens and Nuclear Fuel Services), could be mixed in the same transportation cask if they fall into the same acceptance year.

- Would BWR and PWR assemblies be mixed in the same transportation cask? The question arises at storage locations such as Brunswick and Harris, whose pools have sections for storage of BWR and PWR assemblies, and at locations such as Morris, West Valley, and INEL, where BWR, PWR, and (in the case of INEL) HTG assemblies have been shipped for temporary storage. The assumption in this assessment is "no"—BWR and PWR assemblies would not be mixed in the same transportation cask.

- Would BWR or PWR assemblies discharged from different reactors be mixed in the same transportation cask? The question arises at Morris, which stores BWR assemblies discharged from Cooper Station and Dresden 2, or at McGuire 2, which stores PWR assemblies discharged from the three Oconee reactors as well as the McGuire 2 reactor, or at INEL, which stores PWR assemblies discharged at TMI 2, Surry 1 and 2, Turkey Point 3, and Point Beach. The assumption in this assessment is "no"—BWR or PWR assemblies discharged from different reactors would not be mixed in the same transportation cask.

Among the four shipment grouping criteria discussed above, the last may be considered too restrictive in its application in certain cases. An example is the BWR assemblies stored in the joined Hatch 1 and 2 spent fuel pools, near the Altamaha River about 75 miles west of Savannah, Georgia. These pools contain about 900 BWR assemblies of the 8GS type, about 750 of the 8GP type, and about 1,450 of the 8GB type,[13] each of which has been discharged in substantial numbers from both the Hatch 1 and Hatch 2 reactors. There may be no impediment in mixing such assemblies in the same transportation cask, if they fall into the same acceptance year.

While shipment grouping is considered in this assessment, it is a factor which as a limited effect on the number of transportation casks shipped from a particular site in a particular acceptance year. More elaborate grouping criteria sometimes result in a few additional one or two partially-filled casks shipped from a particular site in a particular acceptance year.

6. CASK OPTIONS

Rail Transport Casks

Several casks are potentially available for rail shipment of SNF or HLW, some of which may also be used for above-ground storage of these materials:

- The NAC STC cask, designed by Nuclear Assurance Corporation, would have a capacity of 26 PWR assemblies at least 6½ years old, or 57 BWR assemblies at least eight years old. The cask would weigh at least 125 tons loaded. The PWR version has been certified by NRC for storage and transport, while the BWR version was scheduled for license submission in the fall of 1995. No NAC STC casks have been fabricated and none are currently available for delivery to storage or shipment sites. It is estimated that fabrication and delivery would take about two years after the order for a certified cask is made.

- The IF-300 cask, designed by General Electric, has a capacity of 7 PWR or 18 BWR assemblies. The cask weighs about 70 tons loaded. Four such casks have been fabricated. Two have been used by Carolina Power and Light for transfer of PWR and BWR assemblies among their Robinson, Brunswick, and Harris facilities. Two are owned by Vectra Technologies, formerly Pacific Nuclear Corporation. The IF-300 is certified for transport only, and no new fabrication is permitted under its current NRC certificate of compliance, which expired in May 1995.

- The TN-8 and TN-9 casks, designed by Transnuclear Inc., have capacities for 3 PWR or 7 BWR assemblies. Assemblies transported in TN-8/9 casks are uncanistered—meaning that, on arrival at its destination, the transportation cask must be moved to a spent fuel pool, where bare fuel assemblies are removed for pool storage or canistering. Though four such casks are available, they are not currently certified for use in the U.S. The TN-8 and TN-9 casks weigh just under 40 tons loaded. They are designed for transport only, not for storage, and the current certificate of compliance expired in May 1996.

- The Hi-Star 100 cask, designed by Holtec International, has a capacity of 24 PWR and 68 BWR assemblies. It is designed for storage as well as transport. None are currently available, as its NRC license application is currently under review. The cask weight, empty or loaded, is currently considered proprietary.

- The Vectra MP-187 cask, designed by Vectra Technologies for storage as well as transport, would have a capacity of 24 PWR assemblies. Its NRC license application is currently under review. The cask is intended for storage and transport of spent fuel at the Rancho Seco plant (near Sacramento, California) which was shut down in 1989.

- The small MPC (multiple-purpose canister) cask, designed by Westinghouse Electric for transport, storage, and (possibly) permanent disposal, would have a capacity of 12 PWR or 24 BWR assemblies. The large MPC cask, also designed by Westinghouse Electric for transport, storage, and (possibly) permanent disposal, would have a capacity of 21 PWR or 40 BWR assemblies.

Through FY 1995, MPC cask design and licensing was supported by DOE via the Nuclear Waste Fund, but this support was not continued in appropriations for FY 1995. While the U.S. Navy is considering an adaptation of the MPC design for the transport and storage of naval reactor fuel, the schedule for its design and licensing for use with SNF is uncertain. It appears unlikely that such casks could be delivered for a 1998 acceptance date.

- DOE has expressed its intention to adapt the MPC design for transport and storage of five canisters of vitrified HLW, each of which would be about 2 feet in diameter and 10 to 15 feet in length.[14] (The 48" diameter cavity of the MPC-75 might accommodate four two-foot diameter canisters, while the 58" diameter cavity of the MPC-125 might accommodate six two-foot diameter canisters.)[15] DOE has not begun detailed design or licensing of such a cask, however.

Dry Storage of Canistered Spent Fuel

Several designs for dry storage of canistered spent fuel have been approved by NRC. In these designs, spent fuel canisters are loaded and sealed in an operating spent fuel pool, then inserted into a nearby concrete or metal facility for onsite storage. The Electric Power Research Institute is currently developing a "dry transfer" facility, by which the sealed canisters could be transferred to a transport cask without return to a spent fuel pool. If successful, dry transfer could enable certain spent fuel pools to be shut down, even while spent fuel remains onsite in dry storage. Dry storage designs include:

- The NUHOMS concrete modules, designed by Vectra Technologies for storage of canistered PWR or BWR assemblies. The NUHOMS-7 design was licensed in 1986 and has a capacity of 7 PWR assemblies, while the NUHOMS-24P design was licensed in 1989 for storage of 24 PWR assemblies. A standardized version of the NUHOMS-24P and NUHOMS-52B (for 52 BWR assemblies) received an NRC certificate of compliance in January 1995.[16] The NUHOMS-7 design is in use at Robinson 2, while the NUHOMS-24P design is in use at Oconee, Calvert Cliffs, and Rancho Seco.

- The VSC-24 ventilated cask, designed by Pacific Sierra Nuclear for storage of 24 PWR assemblies. The design received its NRC certificate of compliance in 1993 and is in use at the Palisades nuclear plant, about 40 miles west of Kalamazoo near the eastern shore of Lake Michigan.

Legal-Weight Truck Transport Casks

Several designs are potentially available for legal-weight truck shipment of SNF and HLW. In contrast to dry storage casks and recently-designed rail casks, legal-weight truck casks are designed to transport uncanistered assemblies—meaning that, on its arrival at its destination, the cask must be placed in a spent fuel pool or hot cell, where the assemblies are removed for pool storage or canistered for dry storage.

- The GA-4 and GA-9 casks, designed by General Atomics, would have capacity for four PWR or nine BWR assemblies. The design is currently in review by NRC. The cask would weigh 27 tons, loaded. Adding the truck and transportation tackle, shipments would barely meet legal highway weight (80,000 lbs.).

There is some question whether General Atomics would find it advantageous to produce the GA-4/9 casks for a shipment campaign which emphasizes rail transport and reduces the inventory shipped by truck. Ironically, the number of smaller capacity truck shipments in a shipment campaign emphasizing rail transport could be as large or larger than the number truck shipments in a campaign which uses the higher capacity GA-4/9 casks combined with less rail transport.

- The NLI-1/2 cask designed by National Lead Industries, but not currently certified for domestic use, and the NAC-LWT cask designed by Nuclear Assurance Corporation have capacity to transport a single 860 pound PWR assembly or two 360 pound BWR assemblies. Such casks have been used in most spent fuel transport to date. These casks weigh 24 to 26 tons loaded.

Transport Cask Options: This Assessment

This assessment limits the array of transport cask options to essentially four:

- A 75-ton rail transport and storage cask similar to the MPC-75 design.
- A 125-ton rail transport and storage cask similar to the MPC-125 design.
- A high-capacity legal-weight truck transport cask similar to the GA-4/9 designs.
- A standard legal-weight truck transport cask similar to the NLI-1/2 or NAC-LWT designs.
- In addition, we have included a 100+ ton rail transport and storage cask for canisters of vitrified HLW—an adaption of the MPC-75/125 designs.

Note that, with the exception of the standard legal-weight truck transport casks, none of the above cask options are licensed by NRC, in production, or currently-available for delivery and use. The GA-4/9 cask design is in review in NRC, but, even if it is licensed, its production is uncertain. Despite considerable DOE investment in the 1990's, the designs for the MPC-75 and 125 casks are conceptual, and have not yet been submitted to NRC for licensing.

This assessment considers the high-capacity and standard capacity truck casks as alternatives for legal-weight truck transport. We estimate truck shipments using either cask, but do not attempt to estimate the mix of high and standard capacity casks that could be used in legal-weight truck shipments.*

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* Map presentation of annual cask shipments (Sections 16-20) assume the use of standard capacity legal-weight truck casks in the "current capabilities" scenario, and the high-capacity, legal-weight truck cask in the "MPC base case" and "maximum rail" transportation choice scenarios.

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7. CASK LOADING

Key Factors in Cask Loading

The facilities at each storage location must be able to load the cask option selected. The key requirements include:

- A crane at the spent fuel pool with operating capacity to safely lift the loaded cask.
- A cask loading area in the spent fuel pool of sufficient dimension to accommodate the upended cask and with a floor capable of supporting the cask during loading.
- A pool depth sufficient to maintain necessary water coverage while assemblies are moved over the upended cask during loading.
- A receiving area of sufficient dimension to accommodate the loading of the upended cask onto the rail car or truck, and a receiving area door of sufficient height to accommodate the rail car or truck along with its horizontally-positioned transport cask.
- In addition, sites with canistered spent fuel stored in concrete modules or vaults (e.g., Robinson, Oconee, Calvert Cliffs, Palisades, Rancho Seco) must have facilities necessary to remove the canisters and load them (wet or dry) into the selected transport cask.

DOE's "FICA" Database

DOE's "Facility Interface Capability Assessment (FICA)" project[17] assessed the capability of each commercial SNF storage facility to handle shipping casks. The assessment, which was conducted in the late 1980s and has not been systematically updated, found one or more limitations at many storage locations (particularly in handling larger and heavier rail casks). Some limitations, however, might be overcome by modifications to facility licenses, administrative controls or physical aspects of the facility.

Application of FICA Data in this Assessment

This assessment has reviewed the FICA data to consider the capability of each storage location to handle the cask options selected (Table 7-1). The key considerations were operating crane capacity, cask loading area dimensions, and pool depth. The assessment recognizes that facilities at some locations have been upgraded since the FICA assessment—particularly with regard to operating crane capacity at sites where onsite dry storage has been developed. The assessment also recognizes that facility limitations are often not absolute; current limitations may be eliminated or reduced through modification of facility licenses, administrative controls or physical aspects of the cask-handling building.

At the same time, the utility must decide that it is advantageous to invest in the changes necessary to enable their facilities to handle cask option "A" rather than cask options "B," or cask option "B" rather than cask options "C" or "D." These decisions "at the margin" will be made in the context of other factors (near-site rail infrastructure, site community characteristics, utility choice criteria) which are discussed in the following sections.

Table 7-1. Cask Loading Factors: by Storage Location

	FUEL STRG LOCATION:	CASK LOADG FACTOR: CRD	CRO	CDI	CLG
1	ARKANSAS NUCLEAR 1	100	100	R125	R125
2	ARKANSAS NUCLEAR 2	100	100	R125	R125
3	ARKANSAS NUCLEAR DRY STRG	NA	NA	NA	NA
4	BEAVER VALLEY 1	125	60	R125	R125
5	BEAVER VALLEY 2	125	100	R125	R125
6	BELLEFONTE 1	ND	ND	ND	ND
7	BELLEFONTE 2	ND	ND	ND	ND
8	BIG ROCK 1	75	24	LWT	LWT
9	BRAIDWOOD 1	125	110	R125	R125
10	BROWNS FERRY 1-2	125	106	R75	LWT
11	BROWNS FERRY 3	125	106	R75	LWT
12	BRUNSWICK 1	125	75	R125	R125
13	BRUNSWICK 1 PWR POOL	125	75	R125	R125
14	BRUNSWICK 2	125	75	R125	R125
15	BRUNSWICK 2 PWR POOL	125	75	R125	R125
16	BYRON 1	125	110	R125	R125
17	CALLAWAY 1	150	125	R125	R125
18	CALVERT CLIFFS 1-2	150	25	R125	R75
19	CALVERT DRY STORAGE	NA	NA	NA	NA
20	CATAWBA 1	125	125	R125	R125
21	CATAWBA 2	125	125	R125	R125
22	CLINTON 1	125	100	R125	R125
23	COMANCHE PEAK 1	130	130	R125	R125
24	COOK 1	150	60	R125	R125
25	COOPER STATION	100	100	LWT	LWT
26	CRYSTAL RIVER 3	120	72	R125	R125
27	DAVIS-BESSE 1	140	125	R125	R125
28	DAVIS-BESSE DRY STRG	NA	NA	NA	NA
29	DIABLO CANYON 1	125	67	R125	R125
30	DIABLO CANYON 2	125	67	R125	R125
31	DRESDEN 1	75	24	LWT	R125
32	DRESDEN 2	75	75	LWT	LWT
33	DRESDEN 3	75	75	LWT	LWT
34	DUANE ARNOLD	100	85	R125	R75
35	ENRICO FERMI 2	125	100	R125	LWT
36	FARLEY 1	125	125	R125	R125
37	FARLEY 2	125	125	R125	R125
38	FITZPATRICK	125	62	R125	R75
39	FORT CALHOUN	75	40	R125	R125
40	FORT ST VRAIN	50	50	LWT	R125
41	FORT ST VRAIN DRY STRG	NA	NA	NA	NA
42	GINNA	40	30	R125	LWT
43	GRAND GULF 1	150	125	R125	R125
44	HADDAM NECK	100	100	R75	LWT
45	HARRIS 1	150	75	R125	R125
46	HARRIS 1 BWR POOL	150	97	LWT	LWT
47	HATCH 1-2	125	125	R125	LWT
48	HOPE CREEK	150	130	R125	R125
49	HUMBOLDT BAY	75	60	R125	R125
50	INDIAN POINT 1	75	60	LWT	LWT
51	INDIAN POINT 2	40	32	R75	LWT
52	INDIAN POINT 3	75	40	R75	LWT
53	KEWAUNEE	125	120	LWT	LWT
54	LACROSSE	50	36	LWT	LWT
55	LASALLE 1-2	125	100	R125	R125
56	LIMERICK 1-2	125	110	R125	R125
57	MAINE YANKEE	125	125	R125	R125
58	MCGUIRE 1	125	100	LWT	R125
59	MCGUIRE 2	125	100	LWT	R125
60	MILLSTONE 1	110	110	LWT	R125
61	MILLSTONE 2	100	100	R125	R125
62	MILLSTONE 3	125	125	R125	R125
63	MONTICELLO	85	85	LWT	LWT
64	NINE MILE POINT 1	125	100	R125	LWT
65	NINE MILE POINT 2	125	100	R125	LWT
66	NORTH ANNA 1&2	125	105	R125	R125
67	NORTH ANNA DRY STRG	NA	NA	NA	NA
68	OCONEE 1&2	100	100	LWT	R125
69	OCONEE 3	100	100	LWT	R125
70	OCONEE DRY STORAGE	NA	NA	NA	NA
71	OYSTER CREEK 1	100	100	R125	R75
72	OYSTER CREEK DRY STRG	NA	NA	NA	NA
73	PALISADES	100	25	LWT	LWT
74	PALISADES DRY STORAGE	NA	NA	NA	NA
75	PALO VERDE 1	150	150	R125	R125
76	PALO VERDE 2	150	150	R125	R125
77	PALO VERDE 3	150	150	R125	R125
78	PEACHBOTTOM 2	125	100	R75	LWT
79	PEACHBOTTOM 3	125	100	R75	LWT
80	PERRY 1	125	125	R125	R125
81	PILGRIM 1	100	26	R75	LWT
82	POINT BEACH 1&2	125	125	R75	R125
83	POINT BEACH DRY STRG	NA	NA	NA	NA
84	PRAIRIE ISLAND 1&2	125	125	R125	R125
85	PRAIRIE ISLAND DRY STRG	NA	NA	NA	NA
86	QUAD CITIES 1	125	75	R125	LWT
87	RANCHO SECO 1	100	97	R125	R125
88	RANCHO SECO DRY STRG	NA	NA	NA	NA
89	RIVER BEND 1	125	125	R125	R125
90	ROBINSON 2	125	77	R75	R125
91	ROBINSON DRY STORAGE	NA	NA	NA	NA
92	SALEM 1	110	110	R125	R125
93	SALEM 2	110	110	R125	R125
94	SAN ONOFRE 1	105	70	R75	LWT
95	SAN ONOFRE 2	125	125	R125	R125
96	SAN ONOFRE 3	125	125	R125	R125
97	SEABROOK 1	125	125	R125	R125
98	SEQUOYAH 1	125	80	R125	R125
99	SHOREHAM	125	123	R75	LWT
100	SOUTH TEXAS 1	150	150	R125	R125
101	SOUTH TEXAS 2	150	150	R125	R125
102	ST LUCIE 1	105	25	R125	R125
103	ST LUCIE 2	150	100	R125	R125
104	SUMMER 1	125	125	R125	R125
105	SURRY 1&2	125	125	R125	R125
106	SURRY DRY STORAGE	NA	NA	NA	NA
107	SUSQUEHANNA 1-2	125	125	R125	R125
108	SUSQUEHANNA DRY STRG	NA	NA	NA	NA
109	THREE MILE ISLAND 1	110	110	R75	R125
110	TROJAN	125	100	R125	R125
111	TURKEY POINT 3	105	25	R125	R75
112	TURKEY POINT 4	105	25	R125	R75
113	VERMONT YANKEE 1	110	110	LWT	LWT
114	VOGTLE 1-2	125	91	R125	R125
115	WASH NUCLEAR 2	125	125	R125	LWT
116	WATTS BAR 1&2	ND	ND	ND	ND
117	WATERFORD 3	125	125	R125	LWT
118	WOLF CREEK 1	150	125	R125	R125
119	YANKEE-ROWE 1	75	37	R75	R125
120	ZION 1&2	125	110	R125	LWT
121	HANFORD SNF STRG	ND	ND	ND	ND
122	HANFORD SNF STRG	ND	ND	ND	ND
123	INEL SNF STRG	ND	ND	ND	ND
124	INEL SNF STRG	ND	ND	ND	ND
125	INEL SNF STRG	ND	ND	ND	ND
126	SAVANNAH RV SNF STRG	ND	ND	ND	ND
127	SAVANNAH RV SNF STRG	ND	ND	ND	ND
128	WEST VALLEY SNF STRG	ND	ND	ND	ND
129	WEST VALLEY SNF STRG	ND	ND	ND	ND
130	MORRIS	125	68	R125	R125
131	MORRIS	125	68	R125	R125
132	GENERAL ATOMICS	ND	ND	ND	ND

Cask Loading Factors:
- CRD: design crane capacity (tons)
- CRO: operating crane capacity (tons)
- CDI: cask set-down (loading) diameter (max cask option)
- CLG: cask length (loading) req (max cask option)

Shipment Cask Options:
- R125: Large MPC for up to 21 PWR or 40 BWR
- R75: Small MPC for up to 12 PWR or 24 BWR
- LWT: Legal-weight truck casks.... GA-4/9 if avail, NLI-1/2 or NAC LWT otherwise

8. NEAR-SITE INFRASTRUCTURE

Sites with Onsite Rail

At many storage locations, a rail line extends to the plant site and to the cask receiving area in the fuel handling building and/or the dry storage facility or barge loading platform. At some such locations, however, the onsite rail line requires upgrading for spent fuel rail shipments.

Sites without Onsite Rail

Locations without onsite rail may choose to transport the rail cask by heavy-haul truck or barge to an offsite railhead where the cask can be loaded onto a rail car for cross-country shipment. Such a decision, however, can introduce complications which could persuade a utility to choose to ship by legal-weight truck, or at least to hesitate before choosing to ship by rail.

- The additional load/unload operation in heavy-haul truck or barge transport is both costly and logistically complex.
- Heavy-haul truck transport involves state regulatory agencies in ways that legal-highway-weight transport does not.
- The communities along the heavy-haul route may object to such shipments.

Branch Rail Line Abandonments

Due to branch rail line abandonments, a number of storage locations which had onsite rail when the reactor was constructed do not have onsite rail now, or may not have onsite rail by the time a national shipment campaign begins. For example:

- The Central Railroad of New Jersey branch rail line, which provided onsite rail access when the Oyster Creek plant was constructed in 1969, has since been abandoned. The nearest currently available railhead is on the Conrail line at Lakehurst, New Jersey, and would be reached via a somewhat circuitous 30-mile heavy-haul truck shipment.
- The Elgin Joliet and Eastern branch rail line which has provided onsite rail access to General Electric's storage facility at Morris, Illinois is being considered for abandonment. The nearest available offsite railhead is on the Santa Fe Railroad at Coal City, and would be reached via a seven-mile heavy-haul truck shipment.

DOE's "NSTI" Database

DOE's Near-Site Transportation Infrastructure (NSTI) project[18] assessed the existing capabilities and upgrade potentials of transportation networks near 76 spent fuel storage sites. The assessment was conducted in 1989, and has not been systematically updated. Also, the NSTI final report makes clear that it does not recommend which transportation mode or shipping route should be used at the 76 sites, or imply that the utility or plant operator for any facility or transportation system has expressed the intention of completing the upgrades assessed (Table 8-1).

Onsite Rail, Plus Rail Cask Loading

In fact, the utility's transportation choice will not be made on the basis of either near-site transportation or storage facility infrastructure, but on the combination of these factors with other considerations. This assessment generally assumes that a site will ship by rail if onsite rail is available and if the storage location facilities are able to load a 75 or 125-ton rail cask. In other words, it is generally assumed that a utility will find it advantageous to ship by rail if the additional investment required is small. For example,

- Arkansas Nuclear 1 and 2, located near Russellville, Arkansas, about 65 miles northwest of Little Rock, is a site which has operating onsite rail, and two separate pools—each capable of loading casks up to 9'6" in diameter and 19'2" in length, and each with an operating crane capacity of 100 tons. In this case, rail shipment using 75-ton casks would appear to require limited additional investment in pool facilities or near-site infrastructure, and it is assumed that this would be the choice of Arkansas Power and Light.

- Perry, located on the south shore of Lake Erie about 35 miles northeast of Cleveland, has operating onsite rail with modest upgrade requirements and two separate pools—each capable of loading casks up to 10'0" in diameter and 20'11" in length, and each with an operating crane capacity of 125 tons. In this case, rail shipment using 125-ton casks would appear to require limited additional investment in pool facilities or near-site infrastructure, and it is assumed this would be the choice of Cleveland Electric Illuminating Company.

No Onsite Rail or Rail Cask Loading

This assessment generally assumes that a site will ship by truck if on-site rail is not available and if current storage location facilities are unable to load a 75 or 125-ton rail cask. In other words, it is generally assumed that a utility will ship by legal-weight truck if the additional cost (in facility upgrades or logistical complication) to ship by rail is large. For example:

- Indian Point, located on the Hudson River about 35 miles north of Times Square, does not have onsite rail, though an offsite railhead is less than five miles distant. The pool at reactor #1, which was shut down in 1980, is capable of loading casks only 3'1" in diameter and 12'11" in length. The pools at reactors 2 and 3 are capable of loading casks of only 7'6" and 8'0" in diameter and 15'10" to 16'2" in length. The operating capacities of the pool cranes are 40 tons or less. In this case, rail shipment would appear to require substantial investment in pool dimensions, crane capacity and heavy-haul logistics. It is assumed that Consolidated Edison would avoid this investment, and ship by legal-weight truck.

- Ginna, located on Lake Ontario about 15 miles east of Rochester, New York, does not have onsite rail, though an offsite railhead is less than five miles distant. Its pools is capable of loading casks of 8'7" in diameter, but only 16'9" in length, and its operating crane capacity is only 30 tons. In this case, rail shipment would appear to require substantial investment in pool dimensions, crane capacity and heavy-haul logistics. It is assumed that Rochester Gas and Electric would avoid this investment, and ship by legal-weight truck.

Near-Site Transportation/Cask Loading Combinations

Many sites have combinations of characteristics that complicate the utility's transportation choice:

- Onsite rail is available but pool facilities are unable to load a 75 or 125-ton rail cask.
- Pool facilities are sufficient but onsite rail is unavailable, or, if available, requires expensive upgrading.
- Pool dimensions are sufficient, but operating crane capacity is insufficient to lift a loaded 75- or 125-ton rail cask.
- Crane capacity could be improved, but requires substantial investment in equipment and drop tests.
- An offsite railhead is available but would require an additional loading (to a heavy-haul truck), plus highway travel through nearby communities, plus state heavy-haul permits.

In such circumstances, utilities must choose among available transportation cask options and make the consequent investment in pool facilities or near-site infrastructure to support the choice. DOE/OCRWM, which is responsible for the national shipment campaign, has an interest in and influence on the utility's choice, but cannot force utility investment beyond what the utility considers reasonable and appropriate. Each utility also has an interest in the success of the national shipment campaign—that is, an interest beyond minimizing the cost of moving spent fuel off its particular sites. In sum, choices among available transportation cask options will be made pool by pool and site by site, based on each utility's choice criteria and in the context of federal policy and the various facility, site and transportation network circumstances at the time the choice must be made. For planning purposes, this assessment specifies the available cask options (section 6), and considers three sets of possible utility transportation choices (section 11). Before reviewing the transportation scenarios, we consider several other choice factors—federal policy, utility choice criteria, and changing circumstances.

Table 8-1. Near-Site Infrastructure: by Storage Location

		NEAR-SITE FACTOR:			
	FUEL STRG LOCATION:	OSR	OP?	OSS	OFD
1	ARKANSAS NUCLEAR 1	Y	Y	0	0
2	ARKANSAS NUCLEAR 2	Y	Y	0	0
3	ARKANSAS NUCLEAR DRY STRG	Y	Y	0	0
4	BEAVER VALLEY 1	Y	Y	0	0
5	BEAVER VALLEY 2	Y	Y	0	0
6	BELLEFONTE 1	ND	ND	ND	ND
7	BELLEFONTE 2	ND	ND	ND	ND
8	BIG ROCK 1	N	NA	0	13
9	BRAIDWOOD 1	Y	Y	10	0
10	BROWNS FERRY 1-2	N	NA	20	9
11	BROWNS FERRY 3	N	NA	20	9
12	BRUNSWICK 1	Y	Y	0	0
13	BRUNSWICK 1 PWR POOL	Y	Y	0	0
14	BRUNSWICK 2	Y	Y	0	0
15	BRUNSWICK 2 PWR POOL	Y	Y	0	0
16	BYRON 1	Y	Y	0	0
17	CALLAWAY 1	N	NA	0	15
18	CALVERT CLIFFS 1-2	N	NA	0	37
19	CALVERT DRY STORAGE	N	NA	0	37
20	CATAWBA 1	Y	N	0	0
21	CATAWBA 2	Y	N	0	0
22	CLINTON 1	Y	N	0	0
23	COMANCHE PEAK 1	Y	Y	125	0
24	COOK 1	Y	N	100	0
25	COOPER STATION	Y	Y	0	0
26	CRYSTAL RIVER 3	Y	Y	80	0
27	DAVIS-BESSE 1	Y	Y	0	0
28	DAVIS-BESSE DRY STRG	Y	Y	0	0
29	DIABLO CANYON 1	N	NA	0	19
30	DIABLO CANYON 2	N	NA	0	19
31	DRESDEN 1	Y	Y	25	0
32	DRESDEN 2	Y	Y	25	0
33	DRESDEN 3	Y	Y	25	0
34	DUANE ARNOLD	Y	Y	0	0
35	ENRICO FERMI 2	Y	N	125	0
36	FARLEY 1	Y	Y	45	0
37	FARLEY 2	Y	Y	45	0
38	FITZPATRICK	Y	Y	10	0
39	FORT CALHOUN	N	NA	0	6
40	FORT ST VRAIN	Y	N	100	0
41	FORT ST VRAIN DRY STRG	Y	N	100	0
42	GINNA	N	NA	0	4
43	GRAND GULF 1	N	NA	0	24
44	HADDAM NECK	N	NA	0	14
45	HARRIS 1	Y	Y	0	0
46	HARRIS 1 BWR POOL	Y	Y	0	0
47	HATCH 1-2	Y	Y	0	0
48	HOPE CREEK	N	NA	0	23
49	HUMBOLDT BAY	Y	Y	150	0
50	INDIAN POINT 1	N	NA	0	3
51	INDIAN POINT 2	N	NA	0	3
52	INDIAN POINT 3	N	NA	0	3
53	KEWAUNEE	N	NA	0	10
54	LACROSSE	Y	N	100	0
55	LASALLE 1-2	Y	Y	0	0
56	LIMERICK 1-2	Y	N	50	0
57	MAINE YANKEE	Y	Y	0	0
58	MCGUIRE 1	Y	N	0	0
59	MCGUIRE 2	Y	N	0	0
60	MILLSTONE 1	Y	N	115	0
61	MILLSTONE 2	Y	N	115	0
62	MILLSTONE 3	Y	N	115	0
63	MONTICELLO	Y	Y	0	0
64	NINE MILE POINT 1	Y	Y	125	0
65	NINE MILE POINT 2	Y	Y	125	0
66	NORTH ANNA 1&2	Y	Y	50	0
67	NORTH ANNA DRY STRG	Y	Y	50	0
68	OCONEE 1&2	N	NA	0	35
69	OCONEE 3	N	NA	0	35
70	OCONEE DRY STORAGE	N	NA	0	35
71	OYSTER CREEK 1	N	NA	0	30
72	OYSTER CREEK DRY STRG	N	NA	0	30
73	PALISADES	N	NA	10	13
74	PALISADES DRY STORAGE	N	NA	10	13
75	PALO VERDE 1	Y	Y	0	0
76	PALO VERDE 2	Y	Y	0	0
77	PALO VERDE 3	Y	Y	0	0
78	PEACHBOTTOM 2	N	NA	0	35
79	PEACHBOTTOM 3	N	NA	0	35
80	PERRY 1	Y	Y	40	0
81	PILGRIM 1	N	NA	0	12
82	POINT BEACH 1&2	N	NA	0	16
83	POINT BEACH DRY STRG	N	NA	0	16
84	PRAIRIE ISLAND 1&2	Y	N	25	0
85	PRAIRIE ISLAND DRY STRG	Y	N	25	0
86	QUAD CITIES 1	Y	N	0	0
87	RANCHO SECO 1	Y	N	0	0
88	RANCHO SECO DRY STRG	Y	N	0	0
89	RIVER BEND 1	Y	N	175	0
90	ROBINSON 2	Y	Y	0	0
91	ROBINSON DRY STORAGE	Y	Y	0	0
92	SALEM 1	N	NA	0	23
93	SALEM 2	N	NA	0	23
94	SAN ONOFRE 1	Y	Y	200	0
95	SAN ONOFRE 2	Y	Y	200	0
96	SAN ONOFRE 3	Y	Y	200	0
97	SEABROOK 1	Y	N	135	0
98	SEQUOYAH 1	Y	Y	10	0
99	SHOREHAM	N	NA	0	10
100	SOUTH TEXAS 1	Y	Y	85	0
101	SOUTH TEXAS 2	Y	Y	85	0
102	ST LUCIE 1	N	NA	0	10
103	ST LUCIE 2	N	NA	0	10
104	SUMMER 1	Y	Y	0	0
105	SURRY 1&2	N	NA	0	30
106	SURRY DRY STORAGE	N	NA	0	30
107	SUSQUEHANNA 1-2	Y	Y	0	0
108	SUSQUEHANNA DRY STRG	Y	Y	0	0
109	THREE MILE ISLAND 1	Y	Y	0	0
110	TROJAN	Y	Y	0	0
111	TURKEY POINT 3	N	NA	0	30
112	TURKEY POINT 4	N	NA	0	30
113	VERMONT YANKEE 1	Y	Y	75	0
114	VOGTLE 1-2	Y	N	25	0
115	WASH NUCLEAR 2	Y	Y	0	0
116	WATTS BAR 1&2				
117	WATERFORD 3	Y	Y	25	0
118	WOLF CREEK 1	Y	N	10	0
119	YANKEE-ROWE 1	N	NA	0	7
120	ZION 1&2	Y	Y	0	0
121	HANFORD SNF STRG	ND	ND	ND	ND
122	HANFORD SNF STRG	ND	ND	ND	ND
123	INEL SNF STRG	ND	ND	ND	ND
124	INEL SNF STRG	ND	ND	ND	ND
125	INEL SNF STRG	ND	ND	ND	ND
126	SAVANNAH RV SNF STRG	ND	ND	ND	ND
127	SAVANNAH RV SNF STRG	ND	ND	ND	ND
128	WEST VALLEY SNF STRG	ND	ND	ND	ND
129	WEST VALLEY SNF STRG	ND	ND	ND	ND
130	MORRIS	Y	Y	0	0
131	MORRIS	Y	Y	0	0
132	GENERAL ATOMICS	ND	ND	ND	ND

Near-Site Infrastructure Considerations:
- OSR: onsite rail (yes, no, not applic)
- OP?: onsite rail operating? (yes, no, not applic)
- OSS: onsite rail upgrade cost (000$)
- OFD: distance to offsite rail (miles)

Shipment Cask Options:
- R125: Large MPC for up to 21 PWR or 40 BWR
- R75: Small MPC for up to 12 PWR or 24 BWR
- LWT: Legal-weight truck casks.... GA-4/9 if avail, NLI-1/2 or NAC LWT otherwise

9. OTHER TRANSPORTATION CHOICE FACTORS

Utility transportation choice decisions will reflect factors in addition to current near-site infrastructure and pool capabilities—e.g., federal policy, utility choice criteria, changes in near-site infrastructure cask handling capabilities, or site community characteristics.

Federal Policies

Federal policies affect utility transportation choices. For example,

- Via the nuclear waste fund, DOE has invested in the design of the GA-4/9 cask and the MPC 75 and 125-ton casks, and has set the parameters for these designs. However, as of FY 1996, DOE withdrew its financial support for design, and indicated that it does not intend to support certification or fabrication of these or other transportation or transportation/storage casks.

- Via the nuclear waste fund, DOE could fund modifications to spent fuel pools or near-site infrastructure at origin sites—modifications which would enable these sites to choose transportation options considered more desirable from the perspective of the national shipment campaign. However, in its draft scope for acquisition of transportation services,[2] DOE states that "OCRWM will not fund any on-site infrastructure modifications or improvements to the purchasers' facilities" (page 1).

- In its May 28, 1996 notice,[2] DOE proposes to delegate major responsibilities for waste acceptance, transportation and storage to contractors operating under competitive fixed price contracts. The resulting transportation choices negotiated with utilities could be quite different from those reached under another decision framework.

- DOE intends to provide the final route links to a permanent repository or centralized storage site in Nevada, and has conducted major studies of alternative heavy-haul and rail routes for this link. In the process, DOE would enable origin sites to choose rail over legal-weight truck transport, without, however, providing an incentive for origin sites to ship by rail.

Utility Choice Criteria

Utilities will have different sets of transportation choice criteria, based on their financial positions, their nuclear waste and other transportation experiences, their relationships with nearby communities, etc. Given the same origin site circumstances, utility "A" might choose to upgrade for rail shipment while utility "B," approaching the same decision from a different perspective, might choose to avoid upgrades and ship by truck.

Changes At or Near Origin Sites

Changes at or near origin sites will affect utility transportation choices at the time those choices must be made—generally, five to ten years from now. For example,

- The development of dry storage facilities often involves investment to enable pools to handle sealed spent fuel canisters, if not loaded transportation/storage casks. The resulting capabilities, many of which were not anticipated in DOE's 1989 FICA study, will be available for off-site transportation as well.

- While mainline railroads are receiving increasing freight traffic, branch lines—some serving nuclear plant sites—are being abandoned. For example,

  — The branch line of the Central Railroad which extended along US-9 through the Oyster Creek (New Jersey) site when the plant was constructed in the late 1960s has since been abandoned. Rail casks would now be heavy-hauled to Conrail's railhead in Lakehurst, New Jersey, along a 30-mile route which avoids the towns of Forked River, Tom's River, and Pinewold. Or, rail casks might be heavy-hauled across US-9 for barge shipment to an off-site railhead.

  — Burlington Northern's rail spur to the Cooper Station plant site on the Missouri River about 60 miles south of Omaha may be abandoned when it is no longer needed for shipments to Morris. Rail shipments might be heavy-hauled 30 miles to a Burlington Northern railhead in Nebraska City, or barged down the Missouri River through St. Joseph and Kansas City to a Union Pacific railhead in Boonville, Missouri.

  — The Elgin, Joliet, and Eastern rail spurs to the Morris and Dresden sites about 40 miles southwest of Chicago may be abandoned, as may Conrail's spur to West Valley, about 35 miles south of Buffalo, New York.

- Community conditions (resident population, community character, etc.) in near-site communities may also change, affecting the utility's transportation choice.

10. TRANSPORTATION CHOICES

Given the factors discussed in Sections 6 through 9, how would the transportation choice actually be made? Using Monticello, Big Rock Point, Point Beach, Salem/Hope Creek, and Enrico Fermi as case study sites, this section illustrates the transportation choice decision as it might be addressed by utilities. Section 11 presents three scenarios of transportation choices for all shipment sites. Appendix A compares the three transportation choice scenarios considered in this assessment with two developed by DOE.

Monticello

Given the cask options identified in Section 6, and the factors discussed in Sections 7 through 9, how would Northern States Power (NSP) choose to ship from its Monticello plant, located on the Mississippi River about 35 miles northwest of Minneapolis? Monticello has operating onsite rail which does not require upgrade for shipment of spent nuclear fuel. It has the operating crane capacity (85 tons) but currently has neither the cask set-down diameter (6'4") nor the maximum cask length (16'5") required to load a small MPC.

- Would NSP upgrade its spent fuel pool loading area and depth in order the ship by small MPC using its onsite rail?
- Would NSP avoid upgrade investments and ship by legal-weight truck, probably using Interstate 94 towards Minneapolis and Interstate 494 to circle the city on its western side?

The current capabilities and MPC base case scenarios assume that NSP chooses to ship by legal-weight truck. The maximum rail scenario, as well as scenarios identified by DOE, assume that NSP chooses to upgrade in order to ship by small MPC.

Big Rock Point

Given the cask options identified in Section 6, and the factors discussed in sections 7 through 9, how would Consumers Power Company choose to ship from its Big Rock Point plant, located on the upper reaches of Lake Michigan? Big Rock does not have onsite rail; rail shipments would require heavy-haul to the Tuscola and Saginaw Bay railhead in Petoskey about 13 miles east of the plant site. Neither the operating crane capacity (24 tons) nor cask set-down diameter (5'11") nor maximum cask length (15'11") at Big Rock Point currently meet requirements for loading a small MPC.

- Would Consumer's Power upgrade its crane and spent fuel loading area and depth in order to heavy-haul small rail casks for shipment from Petoskey?
- Would Consumers Power avoid investment in cask handling upgrades and heavy-haul operations, choosing to ship by legal-weight truck, probably south on I-75 to Flint, then southwest on I-69 through Lansing and west on I-95 through Battle Creek and Kalamazoo?

The current capabilities and MPC base case scenarios assume that Consumers Power chooses to ship by legal-weight truck. The maximum rail scenario (as well as DOE's Transportation Strategy Study

2) assumes that Consumers Power will upgrade its facilities and heavy-haul to Petoskey in order to ship small MPCs by rail.

Point Beach

Given the cask options identified in Section 6, and the factors discussed in Sections 7 through 9, how would Wisconsin Electric Power choose to ship from its Point Beach plant site, located on the western shore of Lake Michigan about 85 miles north of Milwaukee? Point Beach does not have onsite rail; rail shipment would require heavy-haul to a railhead, such as the Fox Valley and Western railhead Wisconsin Central in Kewaunee.[19] It has the operating crane capacity (125 tons) and maximum cask length (18'8") but not the cask set-down diameter (7'10") required to load a large MPC.

- Would Wisconsin Electric upgrade the cask set-down area in its spent fuel loading area in order to heavy-haul large rail casks for shipment from Kewaunee?

- Would Wisconsin Electric ship by legal-weight truck in order to avoid the cost of heavy-hauling small MPC casks to the Kewaunee railhead?

The current capabilities scenario assumes that Wisconsin Electric chooses to ship by legal-weight truck, via I-43 from Manitowoc through Sheboygan to Milwaukee. The MPC base case and maximum rail scenarios (as well as scenarios identified by DOE) assume that Wisconsin Electric chooses to upgrade its cask loading area and heavy-haul off site in order to ship large MPCs by rail.

Salem and Hope Creek

Given the cask options identified in Section 6, and the factors discussed in Sections 7 through 9, how would Public Service Gas and Electric (PSG&E) choose to ship from its Salem and Hope Creek plants on the New Jersey side of the Delaware River, about 12 miles south of Wilmington, Delaware? The sites do not have onsite rail; rail shipment would require heavy-haul 23 miles north to a railhead on the West Jersey Railroad in the Town of Salem. Hope Creek has the cask set-down diameter (11'0"), maximum cask length (19'9") and operating crane capacity (130 tons) required to load a large MPC. Salem has the cask set-down diameter (10'0") and maximum cask length (21'4") but insufficient operating crane capacity (110 tons) to load a large MPC.

- Would PSG&E upgrade operating crane capacity at its Salem facilities in order to heavy-haul large rail casks 23 miles for shipment by rail?

- Would PSG&E ship by legal-weight truck in order to avoid the cost of heavy-hauling or barging small MPC casks?

The current capabilities scenario assumes that PSG&E chooses to ship by legal-weight truck from both its Hope Creek and Salem plants. The MPC base case and maximum rail scenarios assume that PSG&E upgrades operating crane capacity at Salem in order to use the large MPC cask, which in the MPC base case would be heavy-hauled 23 miles to the Salem railhead on the West Jersey railroad, and in the maximum rail scenario would be barged up the Delaware River to a Conrail railhead in Wilmington.

Enrico Fermi

Given the cask options identified in Section 6 and the factors discussed in Section 7 through 9, how would Detroit Edison Company choose to ship from its Enrico Fermi plant on the western shore of Lake Erie, about midway between Detroit, Michigan and Toledo, Ohio? The Fermi site has onsite rail which is not operating and would require significant investment to upgrade for shipment of spent nuclear fuel. While its cask set-down diameter (9'0") meets requirements for a large MPC, its operating crane capacity (100 tons) currently meets requirements only for the small MPC, and its maximum cask length (14'9") currently meets requirements for neither the large nor small MPC.

- Would Detroit Edison upgrade the rail spur, the maximum cask length in its spent fuel loading facilities and its operating crane capacity in order to ship large MPC casks by rail?
- Would it ship by legal-weight truck in order to avoid or postpone some or all of these expenses?

The current capabilities scenario assumes that Detroit Edison chooses to ship by legal-weight truck, probably using I-275 to access I-94 for travel across the southern portion of the state. The MPC base case scenario assumes that Detroit Edison upgrades it facilities and rail spur in order to ship large MPCs north to Detroit and west through Lansing and Battle Creek on Grand Trunk Western rail lines. The maximum rail scenario assumes that Detroit Edison upgrades its facilities but not its rail spur at Fermi, choosing to barge rail casks east across Lake Erie to a railhead in Buffalo.

Table 10-1. Transportation Choice Factors and Scenarios: By Storage Location

		CASK LOADG FACTOR:				NEAR-SITE FACTOR:				TRANSP CHOICE:				
FUEL STRG LOCATION:	WASTE TYPE	CRD	CRO	CDI	CLG	OSR	OP?	OS$	OFD	CCP	MPC	MXR	TS2	APD
MONTICELLO	BWR	85	85	LWT	LWT	Y	Y	0	0	LWT	LWT	R75	R75	R75
BIG ROCK 1	BWR	75	24	LWT	LWT	N	NA	0	13	LWT	LWT	R75	R75	LWT
POINT BEACH 1&2	PWR	125	125	R75	R125	N	NA	0	16	LWT	R125	R125	R125	R125
POINT BEACH DRY STRG	PWR	NA	NA	NA	NA	N	NA	0	16	LWT	R125	R125	R125	R125
HOPE CREEK	BWR	150	130	R125	R125	N	NA	0	23	LWT	R125	R125	R125	R125
SALEM 1	PWR	110	110	R125	R125	N	NA	0	23	LWT	R125	R125	R125	R75
SALEM 2	PWR	110	110	R125	R125	N	NA	0	23	LWT	R125	R125	R125	R75
ENRICO FERMI 2	BWR	125	100	R125	LWT	Y	N	125	0	LWT	R125	R125	R125	R125

Site/Facility Charac:
CRD: design crane capacity (tons)
CRO: operating crane capacity (tons)
CDI: cask set-down (loading) diameter (max cask option)
CLG: cask length (loading) req (max cask option)

OSR: onsite rail (yes, no, not applic)
OP?: onsite rail operating? (yes, no, not applic)
OS$: onsite rail upgrade cost (000$)
OFD: distance to offsite rail (miles)

Shipment Cask Options:
R125: Large MPC for up to 21 PWR or 40 BWR
R75: Small MPC for up to 12 PWR or 24 BWR
LWT: Legal-weight truck casks.... GA-4/9 if avail, NLI-1/2 or NAC LWT otherwise

Transp Choice:
MPC: MPC "Base Case" (NWPO: Jan 1994)
CCP: Current Capabilities (NWPO: May 1996)
MXR: Maximum Rail (NWPO: May 1996)

TR2: NV Transp Stategy, Study 2 (DOE: Feb 1996, Table F-3 & PIC)
APD: MPC Prelim Evaluation (DOE: Mar 1993, Appendix D)

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11. TRANSPORTATION MODE AND CASK CHOICES: THREE SCENARIOS

Considering the factors discussed in sections 8, 9, and 10, this assessment identifies three transportation choice scenarios, each specifying the assumed utility choice among available cask options (see Section 7) for each storage location (see Section 2). These scenarios, detailed in Table 11-1, assume that the utility's transportation choice does not change during the shipment campaign.

The MPC Base Case Scenario

The "MPC base case" set of utility transportation choices reflects previous work conducted by the state of Nevada to represent the most likely highway and rail routes for shipments of nuclear waste to Yucca Mountain using DOE's proposed Multi-Purpose Canister system for nuclear waste storage, transportation, and disposal.[20] For this assessment, the previous MPC base case transportation choice assumptions were reviewed; rail shipments by small and large MPC were specified; transportation choices for defense sites (e.g., Hanford, INEL, SRS, West Valley) and certain other storage locations (e.g., General Atomics research fuel) were specified.

In the MPC base case scenario, spent fuel stored at 17 commercial plant sites (listed below) is shipped by legal-weight truck; all other commercial plant sites ship by small or large MPC. If the high-capacity GA-4/9 cask is not available, the scenario assumes that legal-weight truck shipments would use a cask similar in capacity to the NLI-1/2 or NAC LWT.

Big Rock	Haddam Neck	Peachbottom
Crystal River	Humboldt Bay	Pilgrim
Fitzpatrick	Indian Point	St. Lucie
Fort Calhoun	LaCrosse	Vermont Yankee
Fort St. Vrain	Monticello	Yankee Rowe
Ginna	Palisades	

Spent fuel stored at Hanford, INEL, and West Valley, as well as research fuel stored at sites such as General Atomics are shipped by legal-weight truck in the MPC base case scenario. However, HLW vitrified and stored in canisters at Hanford, INEL and Savannah River is shipped by rail in an MPC adapted for this purpose.

The Current Capabilities Scenario

Assuming that utilities may be reluctant to make major investments to upgrade cask loading capabilities or near-site infrastructure, the current capabilities scenario identifies 15 additional commercial sites which could choose to ship by legal-weight truck, and assumes that the high-capacity GA-4/9 cask is not available:

Browns Ferry	Dresden/Morris	Oconee
Calvert Cliffs	Fermi	Oyster Creek
Cook	Grand Gulf	Point Beach
Cooper Station	Hope Creek/Salem	Surry
Diablo Canyon	Kewaunee	Turkey Point

Furthermore, the current capabilities scenario identifies 14 sites which might choose to ship by small MPC, rather than by large MPC as assumed in the MPC base case:

Arkansas Nuclear	Duane Arnold	Nine Mile Point
Beaver Valley	Harris	North Anna
Braidwood	La Salle	Rancho Seco
Byron	Limerick	Zion
Clinton	McGuire	

Obviously, the current capabilities scenario generates a larger number of shipments with greater highway impacts than does the MPC base case.

The Maximum Rail Scenario

Considering the upgrade potentials at each storage location, and assuming effective incentives for utilities to make the upgrades, the "maximum rail scenario" identifies 14 commercial sites (of the 17 which ship by truck in the MPC base case) which might ship by rail:

Big Rock	LaCrosse	Fitzpatrick
Crystal River	Monticello	Palisades
Fort Calhoun	Pilgrim	Peachbottom
Haddam Neck	Vermont Yankee	St. Lucie
Humboldt Bay	Yankee Rowe	

The sites in columns 1 and 2 above are assumed to upgrade for shipment by small MPC, while those in column 3 are assumed to upgrade for shipment by large MPC. The upgrades reduce the number of commercial sites which ship by truck to three: Ginna, Indian Point, Fort St. Vrain—all of which are assumed to use the high-capacity GA-4/9 cask.

In addition, the maximum rail scenario assumes that Three Mile Island upgrades for shipment by large MPC, rather than by small MPC as in the MPC base case.

DOE's Transportation Choice Assumptions

While DOE has not estimated annual shipments by route segment, several DOE studies consider transportation choices on a site-by-site basis: a 1996 "preliminary transportation strategy study for a potential Nevada repository",[21] and a 1993 evaluation of the use of MPCs in DOE's waste management system.[22] Appendix A reviews the transportation choice assumptions in these DOE studies, comparing them with the transportation choice scenarios outlined above.

Table 11-1. Utility Transportation Choice Scenarios: by Storage Location

	FUEL STRG LOCATION:	TRANSP CHOICE: CCP	MPC	MXR
1	ARKANSAS NUCLEAR 1	R75	R125	R125
2	ARKANSAS NUCLEAR 2	R75	R125	R125
3	ARKANSAS NUCLEAR DRY STRG	R75	R125	R125
4	BEAVER VALLEY 1	R75	R125	R125
5	BEAVER VALLEY 2	R75	R125	R125
6	BELLEFONTE 1	R125	R125	R125
7	BELLEFONTE 2	R125	R125	R125
8	BIG ROCK 1	LWT	LWT	R75
9	BRAIDWOOD 1	R75	R125	R125
10	BROWNS FERRY 1-2	LWT	R125	R125
11	BROWNS FERRY 3	LWT	R125	R125
12	BRUNSWICK 1	R75	R75	R75
13	BRUNSWICK 1 PWR POOL	R75	R75	R75
14	BRUNSWICK 2	R75	R75	R75
15	BRUNSWICK 2 PWR POOL	R75	R75	R75
16	BYRON 1	R75	R125	R125
17	CALLAWAY 1	LWT	R125	R125
18	CALVERT CLIFFS 1-2	LWT	R125	R125
19	CALVERT DRY STORAGE	LWT	R125	R125
20	CATAWBA 1	R125	R125	R125
21	CATAWBA 2	R125	R125	R125
22	CLINTON 1	R75	R125	R125
23	COMANCHE PEAK 1	R125	R125	R125
24	COOK 1	LWT	R125	R125
25	COOPER STATION	LWT	R75	R75
26	CRYSTAL RIVER 3	LWT	LWT	R75
27	DAVIS-BESSE 1	R125	R125	R125
28	DAVIS-BESSE DRY STRG	R125	R125	R125
29	DIABLO CANYON 1	LWT	R125	R125
30	DIABLO CANYON 2	LWT	R125	R125
31	DRESDEN 1	LWT	R75	R75
32	DRESDEN 2	LWT	R75	R75
33	DRESDEN 3	LWT	R75	R75
34	DUANE ARNOLD	R75	R125	R125
35	ENRICO FERMI 2	LWT	R125	R125
36	FARLEY 1	R125	R125	R125
37	FARLEY 2	R125	R125	R125
38	FITZPATRICK	LWT	LWT	R125
39	FORT CALHOUN	LWT	LWT	R75
40	FORT ST VRAIN	LWT	LWT	LWT
41	FORT ST VRAIN DRY STRG	LWT	LWT	LWT
42	GINNA	LWT	LWT	LWT
43	GRAND GULF 1	LWT	R125	R125
44	HADDAM NECK	LWT	LWT	R75
45	HARRIS 1	R75	R125	R125
46	HARRIS 1 BWR POOL	R75	R125	R125
47	HATCH 1-2	R125	R125	R125
48	HOPE CREEK	LWT	R125	R125
49	HUMBOLDT BAY	LWT	LWT	R75
50	INDIAN POINT 1	LWT	LWT	LWT
51	INDIAN POINT 2	LWT	LWT	LWT
52	INDIAN POINT 3	LWT	LWT	LWT
53	KEWAUNEE	LWT	R125	R125
54	LACROSSE	LWT	LWT	R75
55	LASALLE 1-2	R75	R125	R125
56	LIMERICK 1-2	R75	R125	R125
57	MAINE YANKEE	R125	R125	R125
58	MCGUIRE 1	R75	R125	R125
59	MCGUIRE 2	R75	R125	R125
60	MILLSTONE 1	R75	R75	R75
61	MILLSTONE 2	R75	R75	R75
62	MILLSTONE 3	R75	R75	R75
63	MONTICELLO	LWT	LWT	R75
64	NINE MILE POINT 1	R75	R125	R125
65	NINE MILE POINT 2	R75	R125	R125
66	NORTH ANNA 1&2	R75	R125	R125
67	NORTH ANNA DRY STRG	R75	R125	R125
68	OCONEE 1&2	LWT	R125	R125
69	OCONEE 3	LWT	R125	R125
70	OCONEE DRY STORAGE	LWT	R125	R125
71	OYSTER CREEK 1	LWT	R125	R125
72	OYSTER CREEK DRY STRG	LWT	R125	R125
73	PALISADES	LWT	LWT	R125
74	PALISADES DRY STORAGE	LWT	LWT	R125
75	PALO VERDE 1	R125	R125	R125
76	PALO VERDE 2	R125	R125	R125
77	PALO VERDE 3	R125	R125	R125
78	PEACHBOTTOM 2	LWT	LWT	R125
79	PEACHBOTTOM 3	LWT	LWT	R125
80	PERRY 1	R125	R125	R125
81	PILGRIM 1	LWT	LWT	R75
82	POINT BEACH 1&2	LWT	R125	R125
83	POINT BEACH DRY STRG	LWT	R125	R125
84	PRAIRIE ISLAND 1&2	R125	R125	R125
85	PRAIRIE ISLAND DRY STRG	R125	R125	R125
86	QUAD CITIES 1	R75	R75	R75
87	RANCHO SECO 1	R75	R125	R125
88	RANCHO SECO DRY STRG	R75	R125	R125
89	RIVER BEND 1	R125	R125	R125
90	ROBINSON 2	R75	R75	R75
91	ROBINSON DRY STORAGE	R75	R75	R75
92	SALEM 1	LWT	R125	R125
93	SALEM 2	LWT	R125	R125
94	SAN ONOFRE 1	R125	R125	R125
95	SAN ONOFRE 2	R125	R125	R125
96	SAN ONOFRE 3	R125	R125	R125
97	SEABROOK 1	R125	R125	R125
98	SEQUOYAH 1	R125	R125	R125
99	SHOREHAM	NA	NA	NA
100	SOUTH TEXAS 1	R125	R125	R125
101	SOUTH TEXAS 2	R125	R125	R125
102	ST LUCIE 1	LWT	LWT	R125
103	ST LUCIE 2	LWT	LWT	R125
104	SUMMER 1	R125	R125	R125
105	SURRY 1&2	LWT	R125	R125
106	SURRY DRY STORAGE	LWT	R125	R125
107	SUSQUEHANNA 1-2	R125	R125	R125
108	SUSQUEHANNA DRY STRG	R125	R125	R125
109	THREE MILE ISLAND 1	R75	R75	R125
110	TROJAN	R125	R125	R125
111	TURKEY POINT 3	LWT	R125	R125
112	TURKEY POINT 4	LWT	R125	R125
113	VERMONT YANKEE 1	LWT	LWT	R75
114	VOGTLE 1-2	R75	R75	R75
115	WASH NUCLEAR 2	R125	R125	R125
116	WATTS BAR 1&2	R125	R125	R125
117	WATERFORD 3	R125	R125	R125
118	WOLF CREEK 1	R125	R125	R125
119	YANKEE-ROWE 1	LWT	LWT	R75
120	ZION 1&2	R75	R125	R125
121	HANFORD SNF STRG	LWT	LWT	LWT
122	HANFORD SNF STRG	LWT	LWT	LWT
123	INEL SNF STRG	LWT	LWT	LWT
124	INEL SNF STRG	LWT	LWT	LWT
125	INEL SNF STRG	LWT	LWT	LWT
126	SAVANNAH RV SNF STRG	LWT	LWT	LWT
127	SAVANNAH RV SNF STRG	LWT	LWT	LWT
128	WEST VALLEY SNF STRG	LWT	LWT	R125
129	WEST VALLEY SNF STRG	LWT	LWT	R125
130	MORRIS	LWT	R125	R125
131	MORRIS	LWT	R125	R125
132	GENERAL ATOMICS	LWT	LWT	LWT

Transp Choice: CCP: Current Capabilities (MWPO: May 1996)
MPC: MPC "Base Case" (MWPO: Jan 1994)
MXR: Maximum Rail (MWPO: May 1996)

Shipment Cask Options: R125: Large MPC for up to 21 PWR or 40 BWR
R75: Small MPC for up to 12 PWR or 24 BWR
LWT: Legal-weight truck casks.... GA-4/9 if avail, NLI-1/2 or NAC LWT otherwise

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12. CASK SHIPMENTS

The assessment of shipment groups (section 5) determines the assemblies and MTU to be picked up for shipment from a particular storage location in a particular acceptance year. The identification of cask options (section 6) determines the transportation casks available under the particular scenario, and the transportation choice assessment (sections 7 through 11) determines the cask option selected for shipment from each storage location.

The next step in the assessment process is to determine the number of cask shipments from each storage location in each acceptance/pickup year.

- Cask shipments of spent fuel from BWR or PWR reactors are estimated by dividing the number of assemblies in the shipment group by the assembly capacity of the selected cask—rounding up to accommodate any fractions required to ship all assemblies in the group.

- Cask shipments of other spent fuel (e.g., spent fuel from research reactors or HTG assemblies from the Fort St. Vrain reactor) are estimated by dividing the MTU in the shipment group by the average MTU per cask for BWR and PWR assemblies shipped during the same period—generally about .40 MTU per T-1/2 cask, 1.655 MTU per T-4/9 cask, 4.28 MTU per R75 cask and 7.41 MTU per R125 cask. In effect, the assumption is that casks for HTG, research and other wastes will be as efficient as those designed for transport of BWR and PWR assemblies.

- Cask shipments for HLW assume that an MPC-like cask to accommodate five two-foot diameter canisters will be designed and certified for transport of HLW. The estimated shipments of HLW canisters from a particular site is thus divided by five—rounding up to accommodate any remaining canisters in the shipment group.

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13. ROUTING CRITERIA

Having determined the number of shipments of a particular cask type from each site each acceptance year, we must then determine the highway or rail shipment route. Aggregating shipments from each origin site, a community along a particular route segment in Pennsylvania, or in Indiana or Missouri could then understand, for example, that in the second acceptance year it should expect "x" shipments of certain cask types originating from certain storage locations, while in the fifth acceptance year it should expect "y" shipments from a somewhat different set of storage locations. This information should help state and local agencies conduct their planning in the context of the national shipment campaign.

In most cases, the routing decision will be made by the carrier, under certain constraints. Most notable is the requirement (based on 49 CFR§397.101(a), referred to as HM 164), that in transporting radioactive waste by truck, drivers must reduce transit time by using interstate highways or state-designated alternative routes.

In addition to the HM 164 requirement, we also assume that certain routing practices will be followed by shippers and carriers. For example, we assume that shippers will generally choose the closest Class I (highest volume) rail carrier, and that rail carriers will prefer Class A (highest volume) mainline rail segments.

Default (Quickest) Routes

To assist in identifying possible routes for waste shipments, DOE (through the Oak Ridge National Laboratory) has developed and made available two computer-assisted models, HIGHWAY and INTERLINE. In determining the truck shipment routes for this study, the HIGHWAY model[23] was used to calculate the "quickest route" (minimizing travel time) subject to HM 164 requirements. In determining the rail shipment routes, the INTERLINE model[24] was used to calculate the quickest route. In both cases, the models were run without other special limitations, such as avoidance of population centers and recognition of the BN/Santa Fe merger or the anticipated UP/SP merger.*

Consolidated Southern Routes

A second alternative for each route scenario was also developed to consolidate the rail and highway shipments into fewer routes, both to minimize the number of affected communities and to avoid certain seasonal weather conditions or problematic highway segments (e.g., the Eisenhower Tunnel and Glenwood Canyon on I-70 west of Denver). The consolidated route orients truck shipments from the Northeast, Southeast, and Midwest to I-40 in Oklahoma City, generally avoiding I-70 west of Kansas City and I-80 west of Omaha. Compared to their roles under the default routing criteria, I-44 between St. Louis and Oklahoma and I-70 east of St. Louis play more significant roles as a feeders to the consolidated southern route across the western states.

* BN: Burlington Northern; UP: Union Pacific; SP: Southern Pacific

The consolidated route orients rail shipments from the Northeast, Southeast, and Midwest to the Santa Fe rail lines extending southwest from Kansas City through Amarillo and across New Mexico, and Arizona to Daggett in southeastern California. It thereby avoids the UP and SP lines west of Kansas City and Omaha. The route increases feeder shipments along the Burlington Northern lines between Chicago and Kansas City, and on the Norfolk Southern lines between Cleveland and Kansas City, but reduces shipments on the Chicago and North Western lines between Chicago and Omaha. Otherwise, it has limited effects on routing patterns east of the Missouri River.

14. ROUTE IDENTIFICATION AND MAPPING

As currently developed, the HIGHWAY and INTERLINE models describe, but do not map, shipment routes. Figure 14-1 presents the HIGHWAY description of a cross-country truck shipment route to Yucca Mountain, using Oyster Creek (NJ) as the trip origin for illustration purposes:

- The first line of the output shows the origin ("OYSTER CREEK NP, NJ") and the departure date and time.

- The second line shows (reading from left to right):
  — the distance to the nearest "node" or intersection (12.0 miles);
  — the route to that intersection (U.S. Highway 9, or "U9");
  — the name of the node ("TOMS RIVER" at the intersection of "TGSP," or the Garden State Parkway, and "X82," or exit 82, in "NJ");
  — the cumulative distance from the origin (12.0 miles);
  — the cumulative time required to complete travel from the origin to this node ("0:16"); and
  — the date and time of arrival at the node ("2/01 @ 16:19").

- Each line thereafter includes similar information for subsequent links in the route from Oyster Creek to Yucca Mountain.

- According to the model output, the 2,688-mile route from eastern New Jersey to southern Nevada would pass through Pennsylvania, Ohio, Indiana, Illinois, Iowa, Nebraska, Colorado, and Utah; travel time at an average speed of 53.4 miles per hour would be just over 2 days (50.4 hours).

Figure 14-2 presents the INTERLINE description of a cross-country rail route to Yucca Mountain, again using Oyster Creek (NJ) as the trip origin for illustration purposes:

- For each node along the route, the listing indicates the rail carrier, the node number and name, the state in which the node is located, and the cumulative route distance.

- According to the model output, the default rail route under the MPC base case from Oyster Creek to Yucca Mountain would use Conrail lines to travel to Chicago where shipments would be transferred to the Chicago and North Western to Fremont, Nebraska, and from there on the UP to Caliente or Valley. The total travel distance, excluding new rail construction* or heavy-haul segments at either end, is 2,847 miles.

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* Note that INTERLINE assumes construction of a rail spur from Valley to Yucca Mountain, operated by the U.S. government (USG). In this analysis, we assume construction and use of an intermodal transfer facility and a heavy-haul route for all rail shipments.

Mapping HIGHWAY or INTERLINE Route Descriptions

In route mapping, each segment in the model output is identified on a master map of the nation's major highways or railroads. The mapped route can then be shown in relation to state boundaries, county boundaries, or other more detailed information. Mapped routes for all shipment origins reveal combined shipment impacts for each route segment (see Figure 14-1).

Figure 14-1. HIGHWAY Model Output (Oyster Creek to Yucca Mountain: LWT Truck Base Case Route)

Routing through:

0.0			OYSTER CREEK	NP			NJ	0.0	0:00	2/01 @ 16:03
12.0	U9		TOMS RIVER	NW	TGSP	X82	NJ	12.0	0:16	2/01 @ 16:19
2.0	TGSP		PLEASANT PLNS	S	TGSP	X83	NJ	14.0	0:18	2/01 @ 16:21
12.0	TGSPS		GLENDOLA	SW	TGSP	I195	NJ	26.0	0:31	2/01 @ 16:34
30.0	I195		ALLENTOWN	NW	TNJT	I195	NJ	56.0	1:04	2/01 @ 17:07
10.0	INJTS		HEDDING	SE	TNJT	I276	NJ	66.0	1:15	2/01 @ 17:17
7.0	I276#		BRISTOL	N	I276	X29	PA	73.0	1:23	2/01 @ 17:25
31.0	I276S		PORT KENNEDY	SE	I276	I76	PA	104.0	1:56	2/01 @ 17:59
166.0	I76 S		BREEZEWOOD	SW	I70	I76	PA	270.0	5:27	2/01 @ 21:30
86.0	I70 S	I76 S	YOUNGWOOD	SW	I70	I76	PA	356.0	7:01	2/01 @ 23:04
39.0	I70		LABORATORY	NE	I70	I79	PA	395.0	7:44	2/01 @ 23:46
3.0	I70	I79	WASHINGTON	N	I70	I79	PA	398.0	7:47	2/01 @ 23:49
27.0	I70		WHEELING	SE	I470	I70	WV	425.0	8:17	2/02 @ 0:19
12.0	I470		ST CLAIRSVILLE	E	I470	I70	OH	437.0	8:30	2/02 @ 0:32
116.0	I70		COLUMBUS	E	I270	I70	OH	553.0	11:06	2/02 @ 3:08
21.0	I270		COLUMBUS	W	I270	I70	OH	574.0	11:29	2/02 @ 3:31
157.0	I70		INDIANAPOLIS	E	I465	I70	IN	731.0	14:50	2/02 @ 6:52
5.0	I465		INDIANAPOLIS	SE	I465	I74	IN	736.0	14:56	2/02 @ 6:58
13.0	I465	I74	INDIANAPOLIS	SW	I465	I70	IN	749.0	15:10	2/02 @ 7:12
132.0	I70		TEUTOPOLIS	NW	I57	I70	IL	881.0	17:34	2/02 @ 10:36
6.0	I57	I70	EFFINGHAM	SW	I57	I70	IL	887.0	18:11	2/02 @ 11:12
78.0	I70		EDWARDSVILLE	SE	I270	I55	IL	965.0	19:36	2/02 @ 12:37
29.0	I270		ST LOUIS	NW	I270	I70	MO	994.0	20:07	2/02 @ 13:09
227.0	I70		KANSAS CITY	SE	I435	I70	MO	1221.0	24:45	2/02 @ 17:47
33.0	I435		KANSAS CITY	W	I435	I70	KS	1254.0	25:21	2/02 @ 18:22
47.0	I70 S	TKSTS	TOPEKA	E	I470	I70	KS	1301.0	26:12	2/02 @ 19:14
5.0	I470S	TKSTS	TOPEKA	S	I335	I470	KS	1306.0	26:18	2/02 @ 19:19
7.0	I470		TOPEKA	W	I470	I70	KS	1313.0	26:25	2/02 @ 19:27
1049.0	I70		COVE FORT	W	I15	I70	UT	2362.0	48:53	2/03 @ 16:54
242.0	I15		LAS VEGAS				NV	2604.0	54:17	2/03 @ 21:18
86.0	U95		AMARGOSA VALLY		U95	S373	NV	2690.0	55:59	2/03 @ 23:00

Figure 14-2. INTERLINE Model Output, Rail Base Case, Oyster Cr to Yucca Mtn.

RR	NODE	STATE	DIST
CR	1275-TOMS RIVER	NJ	0.
CR	1337-TRENTON	NJ	83.
CR	1454-CONSHOHOCKEN	PA	116.
CR	1525-READING	PA	160.
CR	2350-HARRISBURG	PA	213.
CR	2291-ALTOONA	PA	355.
CR	2254-JOHNSTOWN	PA	391.
CR	2066-BESSEMER	PA	458.
CR	2124-PITTSBURGH	PA	471.
CR	2125-ROCHESTER	PA	497.
CR	2798-ALLIANCE	OH	553.
CR	2763-RAVENNA	OH	570.
CR	2728-CLEVELAND	OH	611.
CR	2633-ELYRIA	OH	638.
CR	3442-TOLEDO	OH	717.
CR	3526-GOSHEN	IN	839.
CR	3525-ELKHART	IN	849.
CR	4022-SOUTH BEND	IN	864.
CR	4067-PORTER	IN	909.
CR	4070-GARY	IN	925.
CR	4073-CLARKE	IN	929.
CR	4074-INDIANA HARBOR	IN	932.
CR	4232-SOUTH CHICAGO	IL	939.
CR	4217-CHICAGO	IL	952.
- - - - -	- - - - - - - - - -	- - -	- - - - TRANSFER
CNW	4217-CHICAGO	IL	952.
CNW	4234-PROVISO	IL	966.
CNW	4311-DE KALB	IL	1008.
CNW	4324-NELSON	IL	1053.
CNW	10304-CLINTON	IA	1086.
CNW	10289-CEDAR RAPIDS	IA	1167.
CNW	10265-MARSHALLTOWN	IA	1234.
CNW	10246-NEVADA	IA	1261.
CNW	10271-AMES	IA	1272.
CNW	10176-MISSOURI VALLEY	IA	1405.
CNW	10198-CALIFORNIA JCT	IA	1411.
CNW	11340-FREMONT	NE	1439.
- - - - -	- - - - - - - - - -	- - -	- - - - TRANSFER
UP	11340-FREMONT	NE	1439.
UP	11406-GRAND ISLAND	NE	1548.
UP	11410-GIBBON	NE	1574.
UP	11352-NORTH PLATTE	NE	1652.
UP	11358-O FALLONS	NE	1701.
UP	13703-JULESBURG	CO	1769.
UP	13465-CHEYENNE	WY	1915.
UP	13462-LARAMIE	WY	1967.
UP	13494-GRANGER	WY	2243.
UP	13568-OGDEN	UT	2382.
UP	13595-SALT LAKE CITY	UT	2417.
UP	13630-LYNNDYL	UT	2530.
UP	14766-VALLEY	NV	2847.
- - - - -	- - - - - - - - - -	- - -	- - - - TRANSFER
USG	14766-VALLEY	NV	2847.
USG	16333-YUCCA MOUNTAIN	NV	2946.

15. SIX ROUTING CASE EXAMPLES

This section describes possible routes to Yucca Mountain from six shipment origin sites. The level of description may be termed "regional" rather than "national" or "local." Key routes, rail carriers, and urban centers are identified, but local features are not. The sites selected are among those which are assumed to make different transportation choices under the current capabilities and maximum rail scenarios, and/or different near-site options for accessing a railhead under the MPC base case and maximum rail scenarios. The description focuses on the possible route, not on the cask options, the transportation choice or the routing criteria. The question of the number and type of prospective shipments along particular route segments is addressed in sections 17 and 18.

Oyster Creek (NJ) to Yucca Mountain (NV)

How might shipments from the Oyster Creek (NJ) nuclear plant, located in Ocean County near Barnegat Bay about 55 miles due east of Philadelphia, travel to Yucca Mountain? Under the "current capabilities" scenario, the transportation choice of GPU Nuclear for shipments from Oyster Creek is legal-weight truck—using the high-capacity GA-9 cask if available, or a transportation cask for two BWR assemblies otherwise:

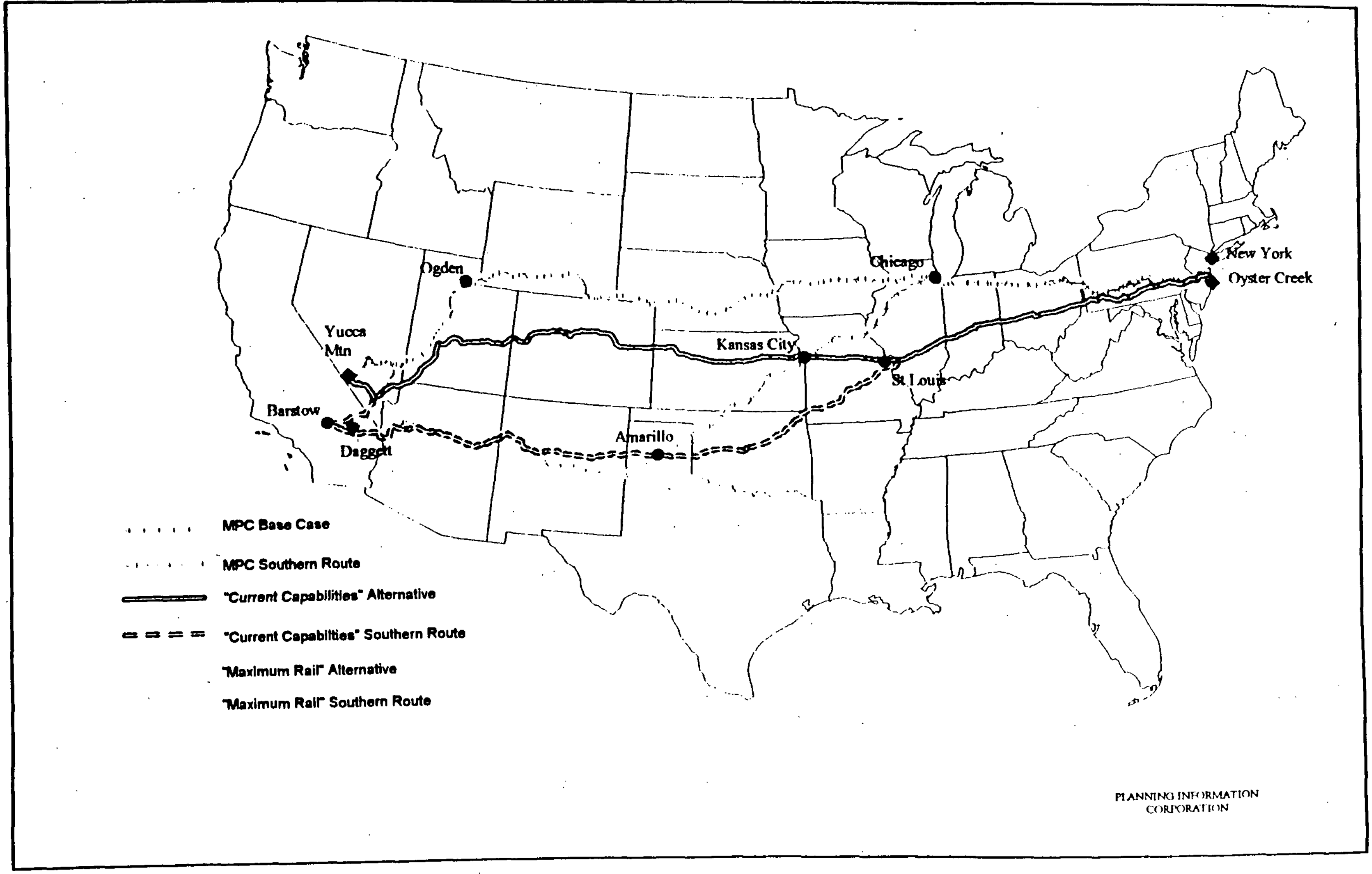
- The "default route" for truck shipments from Oyster Creek would use US 9 and SR-539 to access the Garden State Parkway (a state highway, constructed to interstate standards) northbound at Forked River. The route then continues to I-195 north of Allenwood, to the New Jersey Turnpike and I-276 north of Philadelphia, and to the Pennsylvania Turnpike (I-70 and I-76) through Pennsylvania. From Youngwood in western Pennsylvania, the route continues on I-70 (except for bypasses around major cities) to I-15 in Utah, then through Las Vegas to US 95 and Yucca Mountain.

  The "consolidated southern" option for truck shipments from Oyster Creek would depart from the default route east of St. Louis, continuing on I-70/255 (rather than the I-270 bypass) through East St. Louis, then via I-44 through Tulsa, Oklahoma. From there, the route would follow I-35 to Oklahoma City, I-40 to Barstow, California and I-15 to Las Vegas, US 95 and Yucca Mountain.

Under the "MPC base case" and "maximum rail" scenarios, GPU Nuclear's transportation choice for shipments from Oyster Creek is a large rail cask similar to DOE's 125-ton MPC, containing up to 40 BWR assemblies. However, while the MPC base case assumes heavy-haul transport to the Conrail railhead at Toms River (NJ), the maximum rail scenario would involve barge shipment to Conrail facilities in New York City.[19]

- The "default route" for rail shipments uses different Conrail lines from Toms River (NJ) or New York City to Trenton (NJ).

Figure 15-1. Alternative Nuclear Waste Transportation Routes: Oyster Creek NP



- From Trenton, the default route for rail shipments uses Conrail lines to Chicago (via Conshohocken, PA, Pittsburgh, Cleveland, and Toledo). In Chicago, shipments are transferred to the Chicago and North Western line for travel to Fremont, NB. In Fremont, shipments are transferred to the Union Pacific line for transport (via Grand Island, Cheyenne, Ogden, and Salt Lake City) to an intermodal facility at Caliente or Valley, Nevada.

- The consolidated southern route for rail shipments would depart from the default route in Chicago. In Chicago, shipments would be transferred to the merged Burlington Northern and Southern Pacific lines for travel to Daggett, California (via Kansas City, Amarillo, and Flagstaff). In Daggett, rail shipments would be transferred to the Union Pacific for travel north through Las Vegas to an intermodal transfer facility at Valley or Caliente.

Fermi (MI) to Yucca Mountain (NV)

How might shipments from the Fermi (MI) nuclear plant, located at the western end of Lake Erie, between Toledo and Detroit, travel to Yucca Mountain? Under the "current capabilities" scenario, the transportation choice of Detroit Edison for shipments from Fermi is legal-weight truck—using the high-capacity GA-9 cask if available, or a transportation cask for two BWR assemblies otherwise:

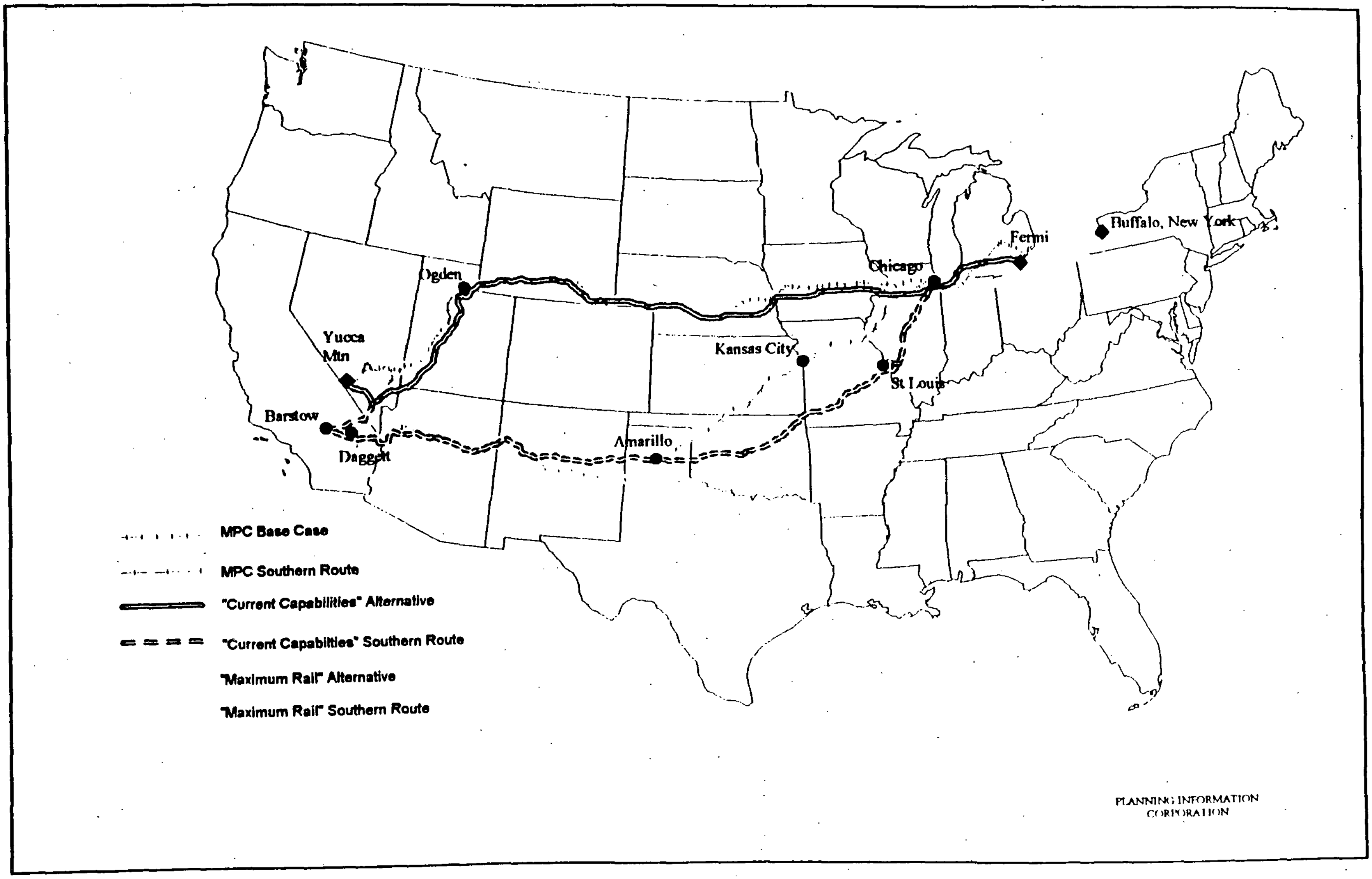
- The "default route" for truck shipments from Fermi would use Interstate 275 (the Detroit metro beltway) to access Interstate 94, which is used to travel across the State of Michigan, passing near Ann Arbor, Jackson, Battle Creek, Kalamazoo, and other cities and towns. The route links with I-80 east of Gary, Indiana, which is used to travel past Chicago and across Iowa, Nebraska, and Wyoming. In Salt Lake City, the default route then links with I-15, which is used for travel south through St. George (UT) and Las Vegas to Yucca Mountain.

- The consolidated southern route for truck shipments from Fermi departs from the default route west of Joliet, Illinois, where, rather than continuing west on I-80, it would access I-55 for travel through Springfield to St. Louis. In St. Louis, the southern route would access I-44 for travel west through Oklahoma City, Amarillo, Albuquerque, and Flagstaff to Barstow, California. In Barstow, the route would access I-15 for travel north to Las Vegas and Yucca Mountain.

Under the "MPC base case" and "maximum rail" scenarios, the transportation choice of Detroit Edison for shipments from Fermi is a large rail cask similar to DOE's 125-ton MPC, containing up to 40 BWR assemblies. However, while the MPC base case assumes use of a substantially upgraded on-site rail spur, the maximum rail scenario would involve barge shipment from the western end of Lake Erie to Conrail facilities in Buffalo (NY) at the eastern end.[19]

- The "default route" for rail shipments from Fermi would use the Grand Trunk Western (GTW) line through Detroit to Blue Island, Illinois where shipments would transfer to the Indiana Harbor Belt line. From Blue Island, the route would travel to the Argo and Proviso yards near Chicago, transferring to the Chicago & North Western (CNW) for transport through Cedar Rapids, Iowa to the UP line at Fremont, Nebraska. From Fremont, Union Pacific lines would be used for travel across Nebraska, Wyoming, and Utah to intermodal facilities at Caliente or Valley.

Figure 15-2. Alternative Nuclear Waste Transportation Routes: Fermi NP



- The consolidated southern route for rail shipments from Fermi would depart from the default roue at the Argo yards near Chicago, where, rather than transferring to the Chicago and Northwestern line, shipments would be transferred to the consolidated Burlington Northern and Santa Fe lines for travel southwest through Galesburg (IL), Kansas City, Amarillo, and Flagstaff to Daggett (CA). In Daggett, rail shipments would be transferred to the UP for travel north through Las Vegas to an intermodal transfer facility at Valley or Caliente.

- Rail shipments from Buffalo (after barge shipment from Fermi, under the maximum rail scenario) would use Conrail lines for travel along the southern shore of Lake Erie through Erie (PA), Cleveland, and Toledo. Shipments would continue on Conrail through Elkhart and South Bend (IN) to the Argo yards near Chicago, where the route would link with routes for rail shipments directly from Fermi.

Browns Ferry (AL) to Yucca Mountain (NV)

How might shipments from the Browns Ferry plants, located across the Tennessee River from the City of Decatur, travel to Yucca Mountain? Under the 'current capabilities" scenario, the transportation choice of the Tennessee Valley Authority for shipments from Browns Ferry is legal-weight truck—using the high-capacity GA-9 cask if available, or a transportation cask for two BWR assemblies otherwise:

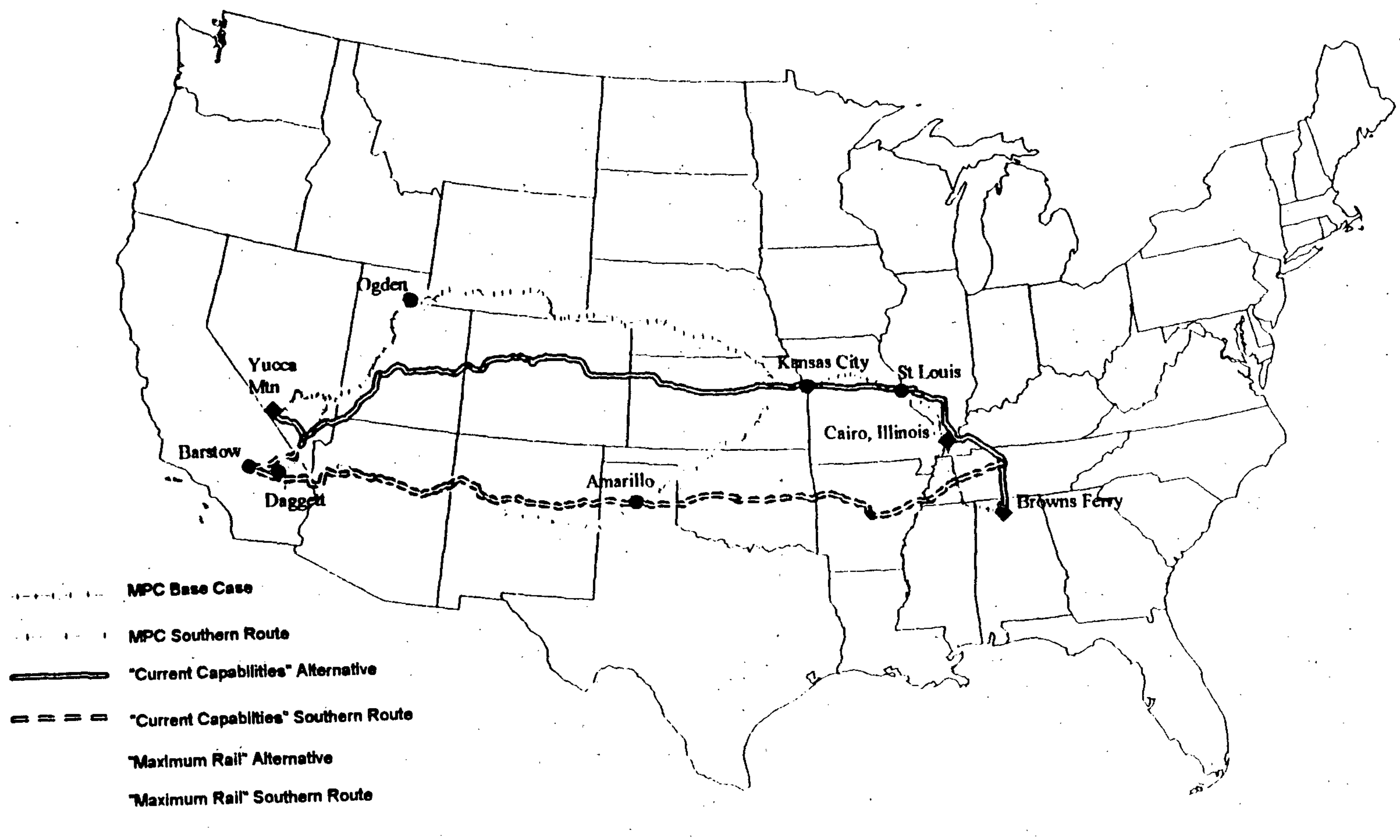
- The "default route" for truck shipments from Browns Ferry would use I-65 to travel north to Nashville, where it would link to I-24 for travel across southwestern Kentucky and southern Illinois to St. Louis. In St. Louis the default route would access I-70 for travel across Missouri to Kansas City, across Kansas and eastern Colorado to Denver, and across western Colorado (through the Eisenhower tunnel and Glenwood Canyon) into Utah. About 160 miles south of Salt Lake City, I-70 links with I-15, which is used for travel south through St. George and Las Vegas to Yucca Mountain.

- The consolidated southern option for truck shipments from Browns Ferry departs from the default route in Nashville, where, rather than continuing west on I-24, it would access I-40 for travel west through Memphis, Little Rock, Oklahoma City, Amarillo, and Albuquerque to Barstow, California. In Barstow, the route would access I-15 for travel north to Las Vegas and Yucca Mountain.

Under the "MPC base case" and "maximum rail" scenarios, the transportation choice of Tennessee Valley Authority for rail shipments from Browns Ferry is a large rail cask similar to DOE's 125-ton MPC, containing up to 40 BWR assemblies. However, while the MPC base case involves heavy-haul transport across the Tennessee River to a Norfolk Southern railhead in Decatur, the maximum rail scenario involves barge shipment down the Tennessee River to Paducah, Kentucky and down the Ohio river to the Illinois Central railhead at Cairo, Illinois:[19]

- The "default route" for rail shipment from Decatur uses Norfolk Southern lines for travel across northern Alabama and Tennessee to Cairo (IL), St. Louis, and Kansas City. In Kansas City, shipments would be transferred to the UP for travel across Nebraska and Wyoming, through Ogden and Salt Lake City (UT) to an intermodal facility at Caliente or Valley.

Figure 15-3. Alternative Nuclear Waste Transportation Routes: Browns Ferry NP



- The consolidated southern route from Decatur would depart from the default route in Kansas City, where, instead of transferring to the UP, shipments would be transferred to the merged Burlington Northern and Santa Fe lines for travel to Daggett, CA (via Amarillo and Flagstaff). In Daggett, rail shipments would be transferred to the UP for travel north through Las Vegas to an intermodal facility at Valley or Caliente.

- Under the maximum rail scenario, rail shipment on the default or consolidated southern route would begin in Cairo, after barge shipment along the Tennessee and Ohio Rivers.

Cooper Station (NE) to Yucca Mountain (NV)

How might shipments from the Cooper Station site, on the Missouri River about 65 miles south of Omaha, travel to Yucca Mountain? Under "current capabilities" scenario, the transportation choice of Nebraska Public Power for shipments from Cooper Station is legal-weight truck—using the high-capacity GA-9 cask if available, or a transportation cask for two BWR assemblies otherwise:

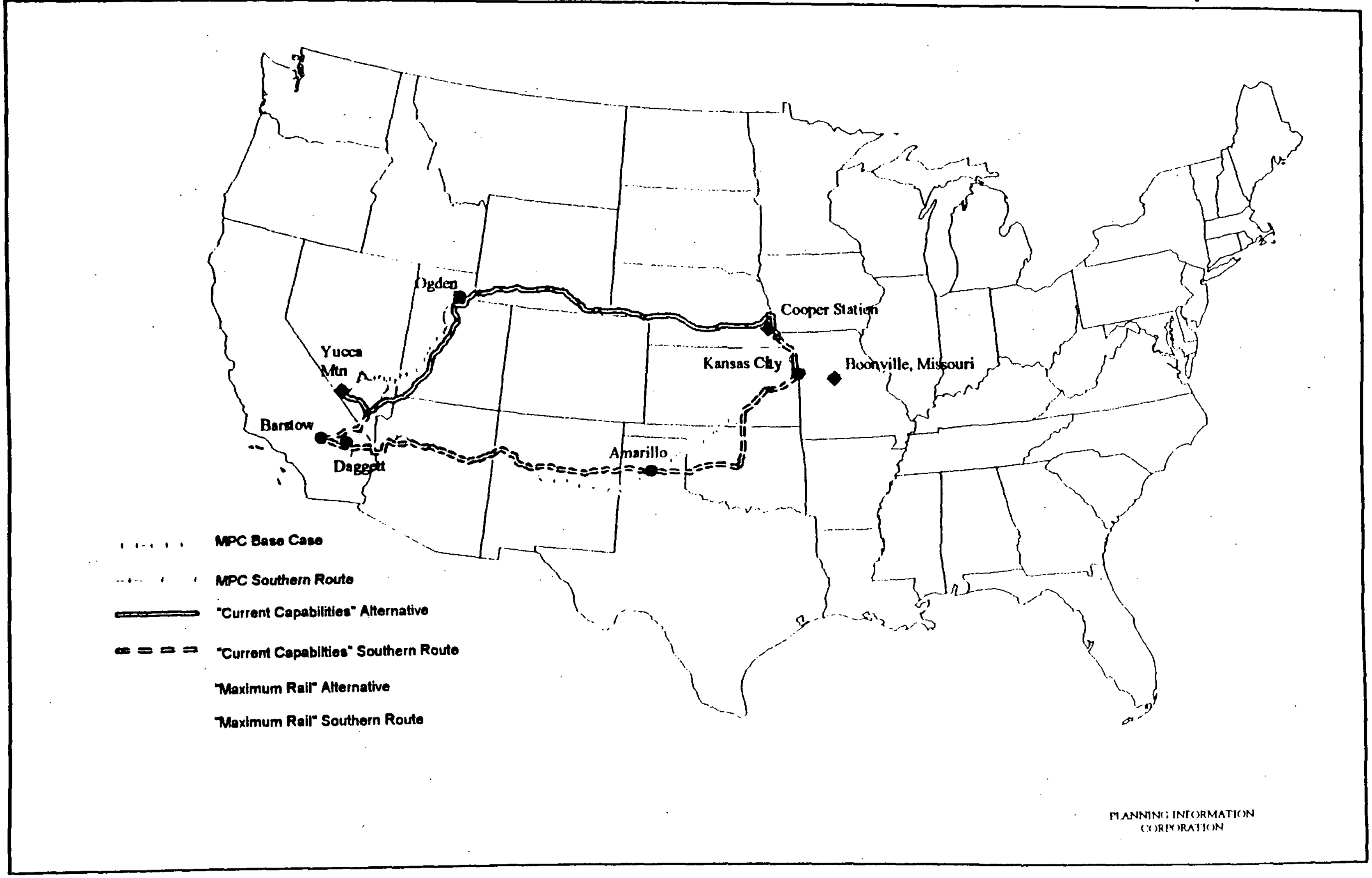
- The "default route" for truck shipments from Cooper Station would follow US 135 west and US 75 north to link with I-80 in Omaha. From Omaha, the route would use I-80 for travel across Nebraska, Wyoming, and Utah, linking with I-15 in Salt Lake City, for travel south through St.. George and Las Vegas to Yucca Mountain.

- The consolidated southern route for truck shipments from Cooper Station would follow US 135 east across the Missouri River, and US 59 south to I-29, continuing south on I-29 through St.. Joseph (MO) to Kansas City. In Kansas City, the southern route would access I-35, which it would follow south through Wichita (KS) to Oklahoma City, where it would access I-40 for continued travel west.

Under the "MPC base case" and "maximum rail" scenarios, Nebraska Public Power's transportation choice for shipments from Cooper Station is a small rail cask similar to DOE's 75-ton MPC, containing up to 24 BWR assemblies. However, while the "MPC base case" assumes heavy-haul transport north to a Burlington Northern railhead in Nebraska City (about 50 miles east of Lincoln), or across the Missouri River and south to a Burlington Northern railhead at Phelps City (MO), the maximum rail scenario assumes barge shipment down the Missouri River to a UP railhead in Boonville, about 120 miles east of Kansas City and about 20 miles west of Columbia (MO):[19]

- The "default route" for rail shipments from Cooper Station involves heavy-haul north to the Burlington Northern railhead at Nebraska City. Burlington Northern lines would be used for travel to Omaha, where shipments would be transferred to the UP railroad for travel west across Nebraska, Wyoming, and Utah, then south through Ogden and Salt Lake City to an intermodal facility at Caliente or Valley.

Figure 15-4. Alternative Nuclear Waste Transportation Routes: Cooper Station NP



- The consolidated southern route for rail shipments from Cooper Station involves heavy-haul east across the Missouri River to the Burlington Northern railhead at Phelps City (MO). The route uses Burlington Northern lines for travel southeast to Kansas City, and Santa Fe lines (now merged with Burlington Northern) for travel southwest and west to Daggett, California, where shipments would be transferred to the UP for travel north through Las Vegas to an intermodal facility at Valley or Caliente.

- Default route rail shipments from Boonville (after barge shipment from Cooper Station) would use UP lines for travel through Kansas City to Gibbon (NE), about 120 miles west of Lincoln, then west across Nebraska and Wyoming, and south from Ogden (UT) to an intermodal facility at Caliente or Valley.

- Consolidated southern route rail shipments from Boonville would transfer to Santa Fe lines in Kansas City, using these for travel through Amarillo to Daggett, California, where they would transfer back to UP lines for travel north through Las Vegas to an intermodal facility at Valley or Caliente.

Grand Gulf (MS) to Yucca Mountain (NV)

How might shipments from the Grand Gulf (MS) nuclear plant, located on the Mississippi River about 30 miles south of Vicksburg, travel to Yucca Mountain? Under the "current capabilities scenario, the transportation choice of Systems Energy Resources for shipments from Grand Gulf is legal-weight truck—using the high-capacity GA-9 cask if available, or a transportation cask for two BWR assemblies otherwise:

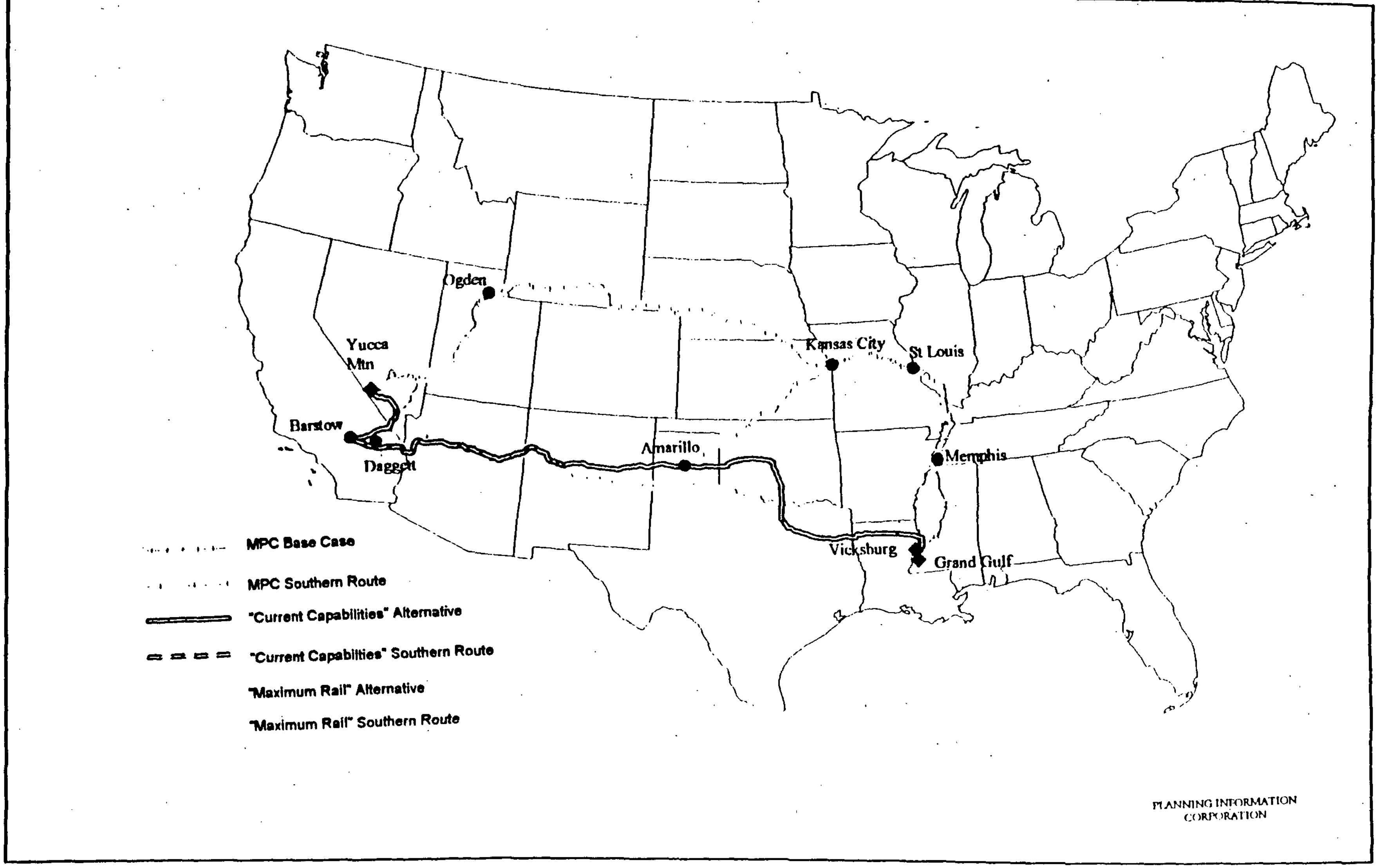
- The default and consolidated southern route for truck shipments from Grand Gulf would follow US 61 north to Vicksburg, where it would link with I-20 for travel west through Shreveport (LA) to Dallas and Fort Worth, where it would access I-35 north to Oklahoma City and I-40 for continued travel west to Barstow, California, where it would access I-15 for travel north through Las Vegas to Yucca Mountain.

Under the MPC base case and maximum rail scenarios, the transportation choice of Systems Energy Resources for shipments from Grand Gulf is a large rail cask similar to DOE's 125-ton MPC, containing up to 40 BWR assemblies:

- The "default route" for rail shipments from Grand Gulf involves heavy-haul north on US 61 and east on I-20 to the Illinois Central railhead at Jackson (MS). The route uses Illinois Central lines for travel north through Memphis to St.. Louis, where shipments would be transferred to UP lines for travel west to Kansas City and across Nebraska, Wyoming, and Utah, then south from Ogden through Salt Lake City to the intermodal facility at Caliente or Valley.

- The consolidated southern route for rail shipments from Grand Gulf departs from the default route in Kansas City where, instead of continuing on the UP, shipments would be transferred to Santa Fe lines for travel southwest to Amarillo and west to Daggett, California, where they would be transferred back to UP lines for travel north through Las Vegas to an intermodal facility at Valley or Caliente.

Figure 15-5. Alternative Nuclear Waste Transportation Routes: Grand Gulf NP



Diablo Canyon (CA) to Yucca Mountain (NV)

How might shipments from the Diablo Canyon (CA) nuclear plant, located on the Pacific Ocean near San Luis Obispo, about 85 miles northwest of Santa Barbara, travel to Yucca Mountain? Under the "current capabilities" scenario, the transportation choice of Pacific Gas and Electric for shipments from Diablo Canyon is legal-weight truck—using the high-capacity GA-4 cask if available, or a transportation cask for a single PWR assembly otherwise:

- The route for truck shipments from Diablo Canyon would follow US-101 north through San Luis Obispo to Paso Robles, and CA 46 east to access I-5 at Lost Hills. The route would follow I-5 southeast towards Los Angeles, accessing I-210 (Foothill Parkway) for passage across LA's northern suburbs—Burbank, Glendale, Pasadena, Glendora, etc. The route accesses I-10 (San Bernadino Freeway) near Pomona, which is used for travel east through Montclair and Ontario to I-15, which is used for travel north through Las Vegas to Yucca Mountain.

Under the MPC base case and maximum rail scenarios, Pacific Gas and Electric's transportation choice for shipments from Diablo Canyon is a large rail cask similar to DOE's 125-ton MPC, containing up to 21 PWR assemblies. However, while the MPC base case assumes heavy-haul transport to the Southern Pacific railhead in San Luis Obispo, the maximum rail scenario involves a 150-mile barge shipment south to Point Conception and east through the Santa Barbara Channel to the railhead of the Ventura County Railway Company at Port Hueneme near Oxnard:[19]

- Rail shipments from San Luis Obispo would use Santa Fe lines for travel through Santa Barbara, Ventura, Oxnard, Burbank, and east Los Angeles to San Bernadino, where they would be transferred to the UP for travel north through Las Vegas to an intermodal facility at Valley or Caliente.

Figure 15-6. Alternative Nuclear Waste Transportation Routes: Diablo Canyon NP

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16. THE NATIONAL SHIPMENT CAMPAIGN: LIFE OF OPERATIONS

What are the overall effects of the national shipment campaign, aggregated for each origin site and all major rail and highway segments over the entire prospective 30-year shipment campaign? What are the effects under the "current capabilities" scenario of transportation choices, or under the "MPC base case" or "maximum rail" scenarios? What are the effects of using a high capacity cask for legal-weight truck shipments,* rather than the currently-available casks limited to one PWR or 2 BWR assemblies?

This section uses maps to present the rail and highway segments affected, and tables to present the total (life of operations) cask shipments in the 30-year shipment campaign. Both maps and tables reflect factors discussed in previous sections—e.g., the current and projected inventory, the acceptance rate and pickup schedule. Under these assumptions, shipments of HLW from DOE sites begin in year 17 and extend through year 44; only those shipments in years 17 through 31 (54 percent of the total) are included in this summary. Subsequent sections consider implications for Nevada (section 17), regional routing alternatives (section 18), the phasing of shipments during the 30-year campaign (section 19), and transportation operations variables (section 20).

Mapping Routes and Cask Shipments

To visualize the cask shipment findings of a multi-faceted assessment process, this study has developed a map presentation in which route segments are scaled according to the number of projected shipments on each segment over the 30-year shipment campaign. The scale is consistent among cask options and among transportation choice scenarios. That is, in this presentation, 100 prospective cask shipments are shown at the same map scale whether the shipments are truck casks containing 1 PWR or 2 BWR assemblies, high-capacity truck casks containing 4 PWR or 9 BWR assemblies, a small rail cask containing 12 PWR or 24 BWR assemblies or a large rail cask containing 21 PWR or 40 BWR assemblies.** The amount of waste shipped in these casks ranges from about 800 pounds in the case of the small truck cask to about 14,800 pounds in the case of the large rail cask, a factor of 18. Another map presentation might be developed to show the amount of waste shipped, rather than the number of cask shipments.

Rail and Highway Routes Affected

Figure 16-1 shows the rail and highway routes affected by default routing under the current capabilities scenario of transportation choices, scaling the routes according to the number of projected shipments on each segment over the 30-year shipment campaign. Figures 16-2 and 16-3 present similar results for the "MPC base case" and "maximum rail" scenarios of transportation choices. Over the 30-year shipment campaign (and assuming default routing), about 18,800 miles of the nation's railroads carry

* A cask similar to the GA-4/9 cask designed by General Atomics, with capacity for 4 PWR or 9 BWR uncanistered assemblies.

** Also, no attempt has been made to project rail consists. The maps indicate the number of casks shipped on each rail route segment, not the number of trains containing cask shipments.

shipments of SNF or HLW, a figure which increases to 21,200 miles under the MPC base case and to 23,500 under the maximum rail scenario of transportation choices.* Rail rather than highway shipment from certain sites (e.g., Turkey Point, FL, Diablo Canyon, CA, Kewaunee, WI) adds significantly to total affected rail route mileage, but from other sites (e.g., Dresden, IL, Browns Ferry, AL) has much less effect.

Over the 30-year shipment campaign (again, assuming default routing) about 13,700 miles of the nation's highways carry shipments of SNF or HLW, a figure which decreases to 10,200 miles under the MPC base case and to 4,200 under the maximum rail scenario of transportation choices. Rail rather than highway shipment from certain sites (e.g., Grand Gulf, MS, Surry, VA, Peachbottom, PA) significantly reduces highway route mileage, but from other sites (e.g., Calvert Cliffs, MD, Salem, NJ) has much less effect.

Total Cask Shipments

Table 16-1 presents total cask shipments over the 30-year campaign, under the current capabilities, MPC base case and maximum rail scenarios. Rail cask shipments of SNF** increase from about 9,900 in the current capabilities scenario of transportation choices to about 11,200 under the MPC base case and 14,100 under the maximum rail scenario. The changes reflect both the number of sites shipping by rail (and their projected inventory) and the type of rail cask used. Compared to the current capabilities scenario, the MPC base case and maximum rail scenarios include more rail shipment sites (*increasing* the number of rail cask shipments) making greater use of the large MPC (*reducing* the number of rail cask shipments). Shipments of uncanistered fuel in currently-available legal-weight truck casks are estimated at 79,300 under the current capabilities scenario of transportation choices, a figure which decreases to 26,100 under the MPC base case and to 4,700 under the maximum rail scenario. The decreases reflect the number of sites shipping by truck rather than by rail, and the projected inventory requiring shipment.

The high-capacity legal-weight truck cask (if available and consistently used throughout the 30-year shipment campaign) dramatically reduces the number of truck cask shipments from 79,300 to 31,400 under the current capabilities scenario, from 26,100 to 6,300 under the MPC base case, and from 4,700 to 1,150 under the maximum rail scenario. Even so, truck cask shipments of SNF would comprise about 71 percent of total cask shipments under the current capabilities scenario, about 31 percent under the MPC base case scenario, and over 6 percent under the maximum rail scenario of transportation choices.

The Use of Affected Rail and Highway Routes

How intensively would the nation's rail and highway networks be used by the national shipment campaign? Over the 30-year campaign, each affected rail route mile would receive an average of about 1,500 cask shipments under the current capabilities scenario, with similar figures for a somewhat more extensive affected rail route network under the MPC base case and maximum rail scenarios. More intensively used rail route segments, however, could receive up to 8.5 times the national average.

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* Route mileage excludes 162 miles of heavy-haul from an intermodal transfer facility at Caliente.

** An additional 2,700 rail cask shipments of HLW are expected between years 17 and 31.

Over the 30-year shipment campaign, each affected rail route mile would receive an average of 13,700 cask shipments under the current capabilities scenario (using currently-available legal-weight truck casks), or about 1,500 shipments (using the high-capacity legal-weight truck cask) under the MPC base case, or about 700 under the maximum rail scenario. Again, more intensively used highway route segments could receive up to six times the national average.

A State-Level Review

Perspectives on nuclear waste transportation are highly correlated with the degree to which waste will be shipped out of, through or to one's own community—that is, the degree to which one's community serves as an origin, corridor or destination for shipments of these highly-toxic and long-lived radioactive materials. Origin communities have lived with nuclear sites for years, even decades, have directly benefited from the electricity and jobs produced, and, with shipment, have the opportunity to rid themselves of the resulting wastes. Corridor communities provide transportation routes for wastes whose origin and destination are elsewhere. Under safe, routine conditions, waste shipments will not linger in corridor communities, but they require attention by public officials and raise anxieties among residents. Destination communities receive the wastes generated elsewhere. In the case of spent nuclear fuel and high-level waste, there is only one prospective destination community, and the waste received, even if safely contained, will remain toxic for centuries.

Under the MPC base case scenario of transportation choices (assuming default routing) only seven states are neither origins, corridors, nor the destination for shipments of SNF or HLW (see Figure 16-4). Together, these jurisdictions comprise 2.4 percent of the nation's population. Another seven states located along the perimeter of the country are origins but not corridors for shipments of SNF and HLW. Together, these states comprise 18 percent of the nation's population. It should be observed, however, that many communities within these states will consider themselves as corridors rather than as origins for shipments of nuclear waste. Still another seven states (three east of the Mississippi River) plus the District of Columbia are corridors but not origins for shipments of SNF and HLW. Together, these states comprise seven percent of the nation's population.

Most states are both origins and corridors for prospective shipments of SNF and HLW under the MPC base case scenario of transportation choices with default routing. Together, these 28 states comprise 71 percent of the nation's population. Five of the 28 are origins for shipments from one (or in the case of Nebraska, two) nuclear site, but are corridors for shipments from 20 sites or more. These states are Iowa, Kansas, Missouri, Nebraska, and Arizona. Together, they comprise 6.2 percent of the nation's population.

Under the MPC base case scenario with default routing, 8 states are corridors for shipments from 25 or more sites. These states, including five with commercial reactors and two east of the Mississippi, comprise 11 percent of the nation's population. Illinois is a corridor state for 47 sites and an origin state for eight sites.

Nevada is the destination state, the end of the funnel for the national shipment campaign and the intended permanent disposal site for the nation's SNF and HLW. Nevada has 0.5 percent of the nation's population. Similar to origin-only states, parts of Nevada are likely to consider themselves more as corridors than as the destination for shipments of SNF and HLW. But these communities are corridors for all shipment sites, and are in the destination state where the wastes will be permanently stored, not an origin state that has previously chosen to developed nuclear power and is now removing the resulting wastes. Section 17 provides additional detail regarding cask shipments into the destination state.

Table 16-1. Route Miles Affected and Cask Shipments
- **Life of Operations (YR 1-31) . . . Default Routing**
- **Currently-Available and High-Capacity Truck Cask**

	RAIL	HWY:T1/2	TOT:T1/2	HWY:T4/9	TOT:T4/9
ROUTE MILES:					
Current Capabilities	18805	13695	32500	13695	32500
MPC Base Case	21210	10224	31434	10224	31434
Maximum Rail	23507	4178	27685	4178	27685
CASK SHIPMENTS:					
Current Capabilities	12636	79345	91981	31370	44006
MPC Base Case	13916	26093	40009	6322	20238
Maximum Rail	16792	4722	21514	1150	17942
CASK SHIP PER RT-MILE:					
Current Capabilities	1496	13356	6493	3154	2194
MPC Base Case	1463	6505	3103	1536	1487
Maximum Rail	1494	2764	1686	703	1375

Table 16-2. States by Origin/Corridor Status

Neither Origins Nor Corridors	Origin Only States	Corridor Only States	Major Corridor States*	
Rhode Island	Michigan	Indiana	Utah	(65/0)
District of Columbia	Wisconsin	Kentucky	Nebraska	(60/2)
Delaware	Maine	Oklahoma	Wyoming	(58/0)
Alaska	New Jersey	West Virginia	Illinois	(47/8)
Hawaii	Florida	New Mexico	Iowa	(32/1)
Montana	Louisiana	Utah	Kansas	(28/1)
North Dakota	Washington	Wyoming	Missouri	(27/1)
South Dakota			Indiana	(25/0)
Percent of U.S. population:	18 percent	7 percent	11 percent	

* (60/2): corridor for 60 sites, origin for 2.

**Figure 16-1. Life of Operations Rail and Highway Cask Shipments
Current Capabilities Transportation Choices/Default Routing**

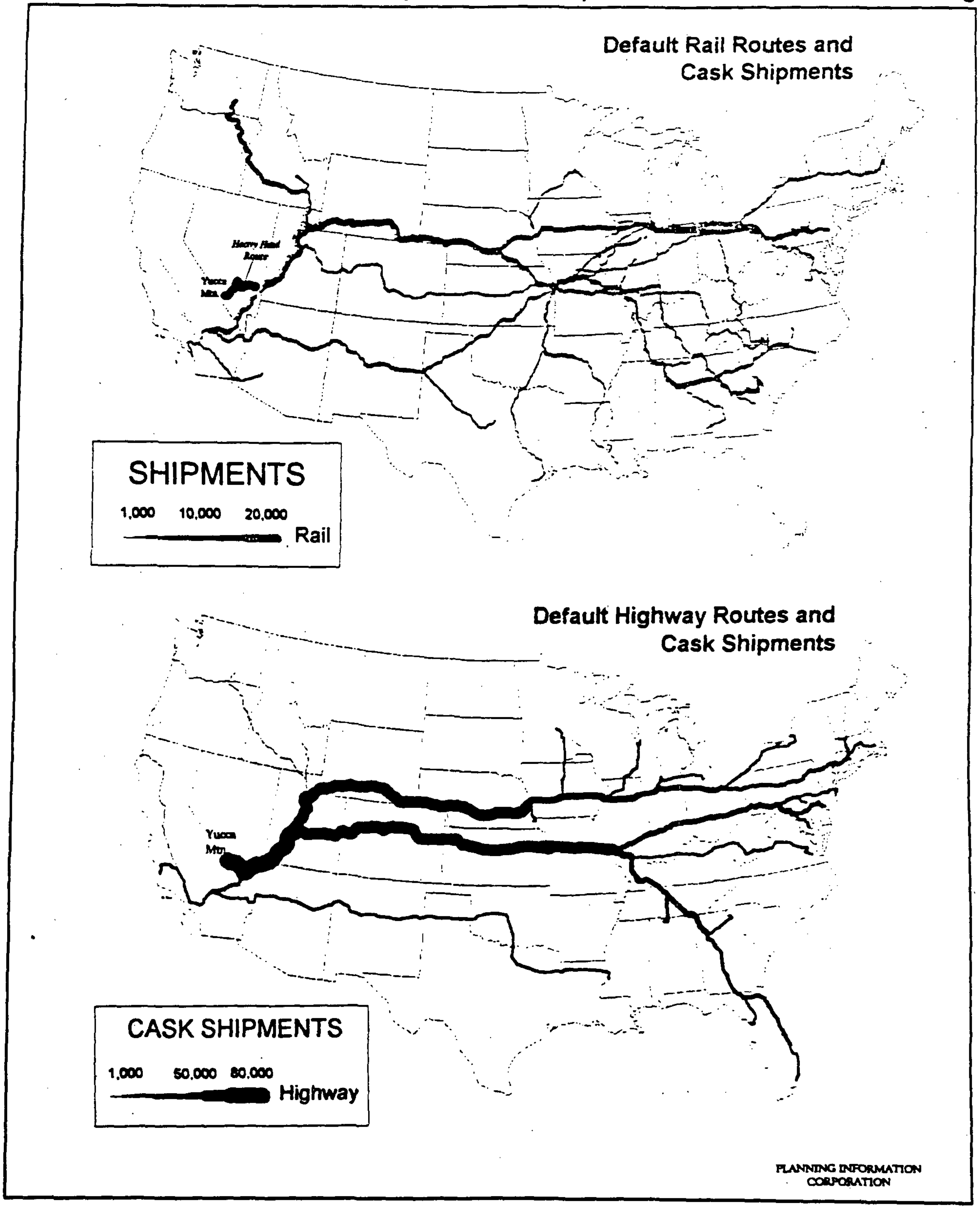


Figure 16-2. Life of Operations Rail and Highway Cask Shipments
MPC Base Case Transportation Choices/Default Routing

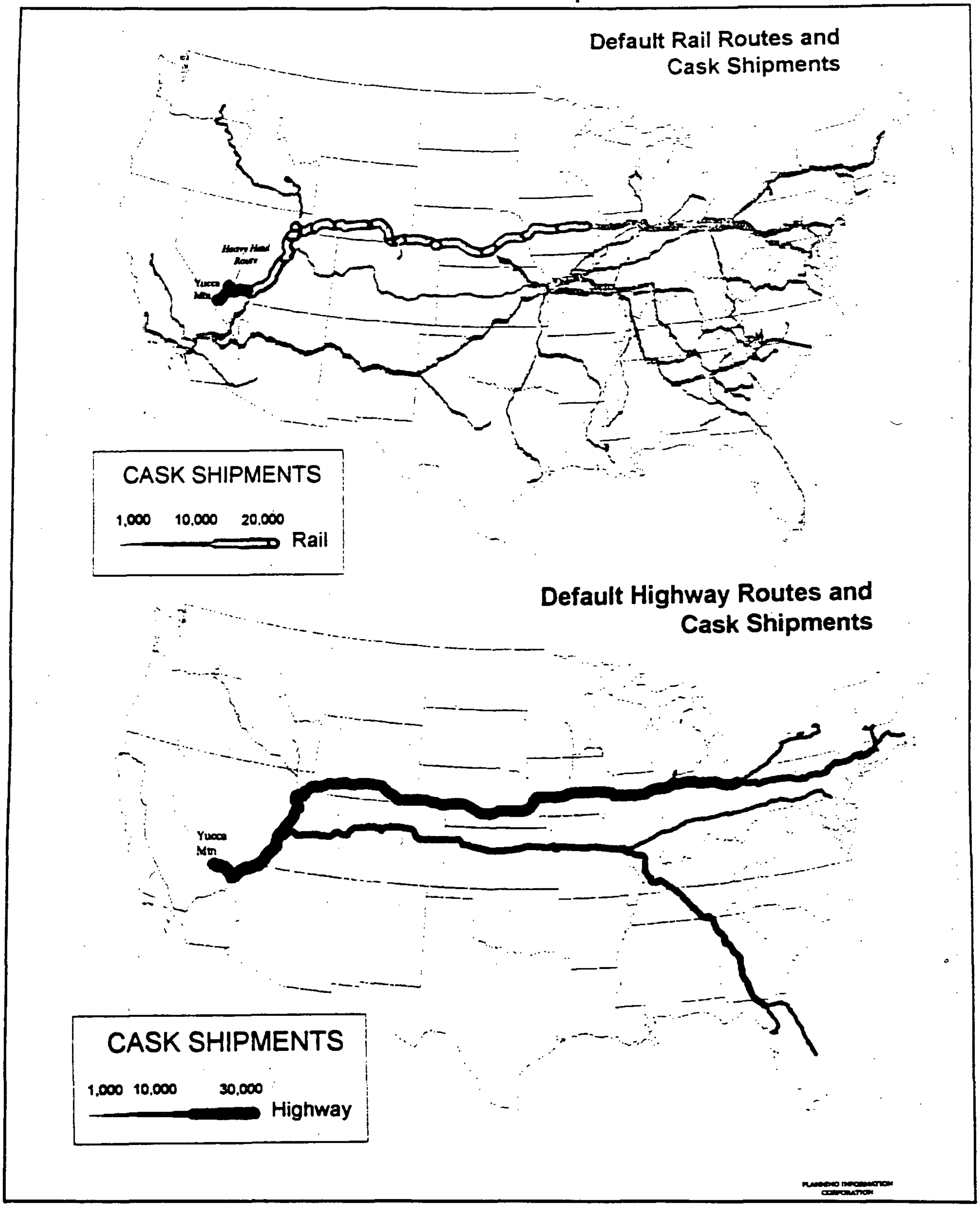
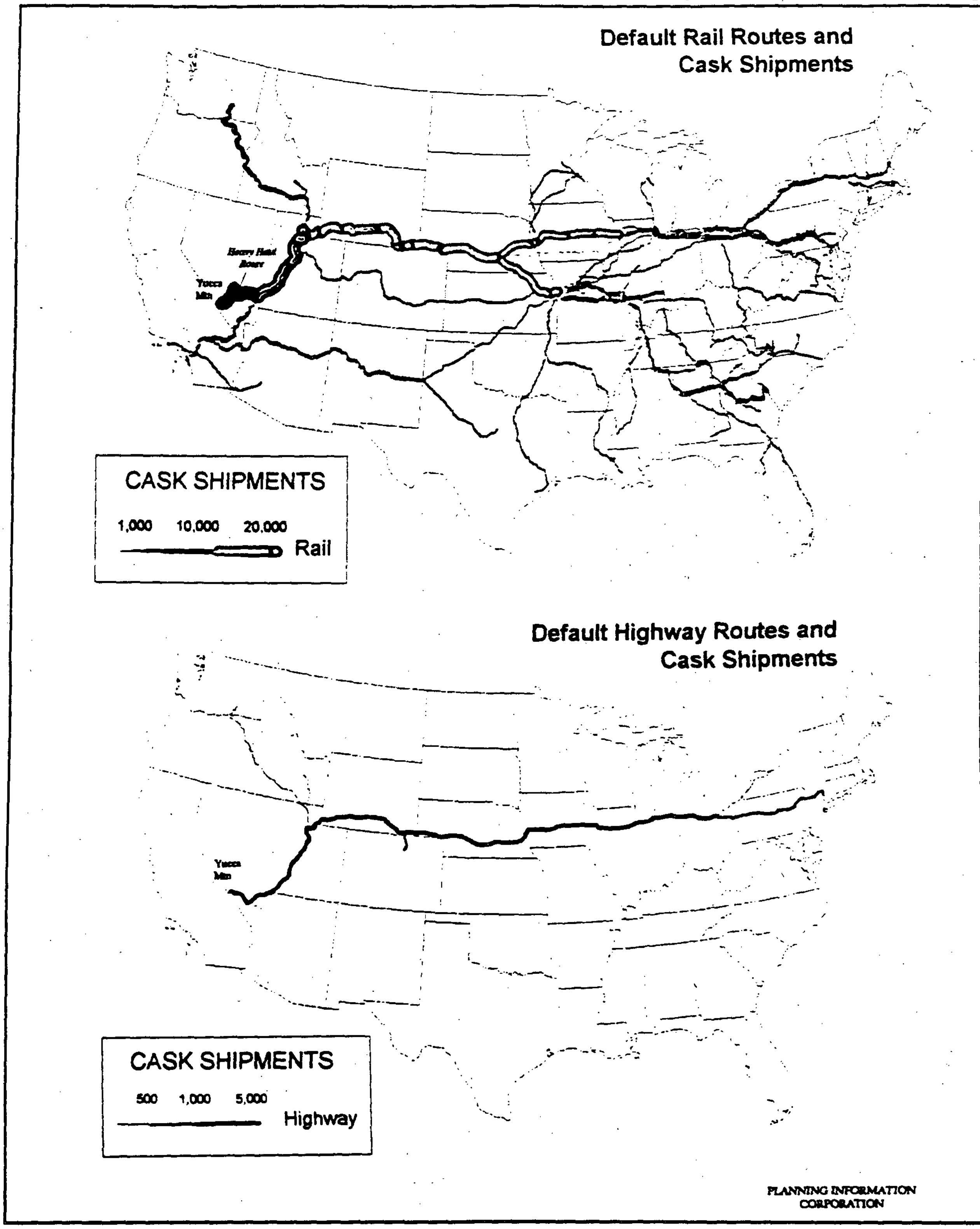


Figure 16-3. Life of Operations Rail and Highway Cask Shipments Maximum Rail Transportation/Default Routing



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17. NEVADA IMPLICATIONS: THE END OF THE FUNNEL

The end of the funnel for the prospective national shipment campaign is Nevada, where rail and truck shipments from 80 sites in 35 states would converge. Under default routing, rail shipments would move on the Union Pacific rail line north from California or south from Utah to an intermodal transfer facility at the Lincoln County community of Caliente. From Caliente, shipments would continue by heavy-haul truck along U.S. highways and state roads, accessing NTS Area 25 via a newly constructed road across a corner of the Nellis Air Force Range, or continuing on public highways along a circuitous route north and west of the Nellis Air Force Range. Truck shipments would move on Interstate 15 north from California or south from Utah and Arizona to a major interchange with US-95/93 in the heart of Las Vegas, locally known as "the Spaghetti Bowl." From the Spaghetti Bowl, truck shipments would continue northwest on US-95, entering the Nevada Test Site at Lathrop Wells in the Nye County community of Amargosa Valley.

Figure 17-1 shows the rail and highway routes affected by default routing under the current capabilities scenario of transportation choices, scaling the routes according to the number of projected shipments on each segment over the 30-year shipment campaign. Figures 17-2 and 17-3 present similar information for the "MPC base case" and "maximum rail" scenarios of transportation choices.

Table 17-1 presents total cask shipments over the 30-year shipment campaign, under the current capabilities, MPC base case and maximum rail scenarios. Under the current capabilities scenario assuming default routing, Nevada would receive about 12,600 rail cask shipments, of which about 9.2 percent would move north from California through Las Vegas. The state would also receive about 79,300 truck shipments (31,300 using the high-capacity T-4/9 cask) of uncanistered fuel, of which about 8.3 percent would move north from California to the Spaghetti Bowl.

Under the MPC base case scenario of transportation choices, rail cask shipments into the state would increase from 12,600 to about 13,900 while truck cask shipments would decrease from 79,300 to 26,100 (from 31,300 to 6,300 using the high-capacity T-4/9 cask). Assuming default routing, the portion of rail and truck shipments moving north into the state from California or south from Utah would change only slightly.

Under the maximum rail scenario of transportation choices, rail cask shipments would increase to 16,800 while truck cask shipments would decrease to 4,700 (to 1,200 using the high-capacity T-4/9 cask). Again, assuming default routing, the portion of rail and truck shipments moving north into the state from California or south from Utah would change only slightly.

Part of a strategy to limit the impacts of transportation shipments in Nevada could involve efforts to avoid Las Vegas, the major urban center of the state. Such a strategy would emphasize rail shipment from the north (where shipments can be intercepted at Caliente) rather than rail shipment from the south or truck shipment on I-15, from the north or south. Among the alternatives considered in this assessment, the maximum rail scenario using default routing (combined with truck shipment using the high-capacity T-4/9 cask) goes the farthest towards this objective. Unfortunately implementation of the maximum rail scenario requires an expensive and not yet devised set of incentives for the choice of rail over truck shipment, and for large rail over small rail shipment. Furthermore, default routing has implications for corridor communities "upstream" in the route system for shipments of SNF and HLW, which we address in the next section. In addition, even if these arrangements and commitments could be made, it is difficult to envision that they could be implemented in time for a shipment campaign beginning in 1998.

Table 17-1. Life of Operations Rail and Highway Cask Shipments Nevada Rail and Highway Route Segments

	CURRENT CAPABIL	MPC BASE CASE	MAXIMUM RAIL
Rail Segments:			
NV: UP @ UT line	11485	12399	15405
NV: UP @ LV Strip	1151	1517	1387
Hwy Segments:			
NV: I-15 @ Moapa	72768	6277	1150
NV: I-15 @ Strip	6577	45	0

Figure 17-1. Life of Operations Rail & Highway Shipments in Southern NV Region Current Capabilities Transportation Choices/Default Routing

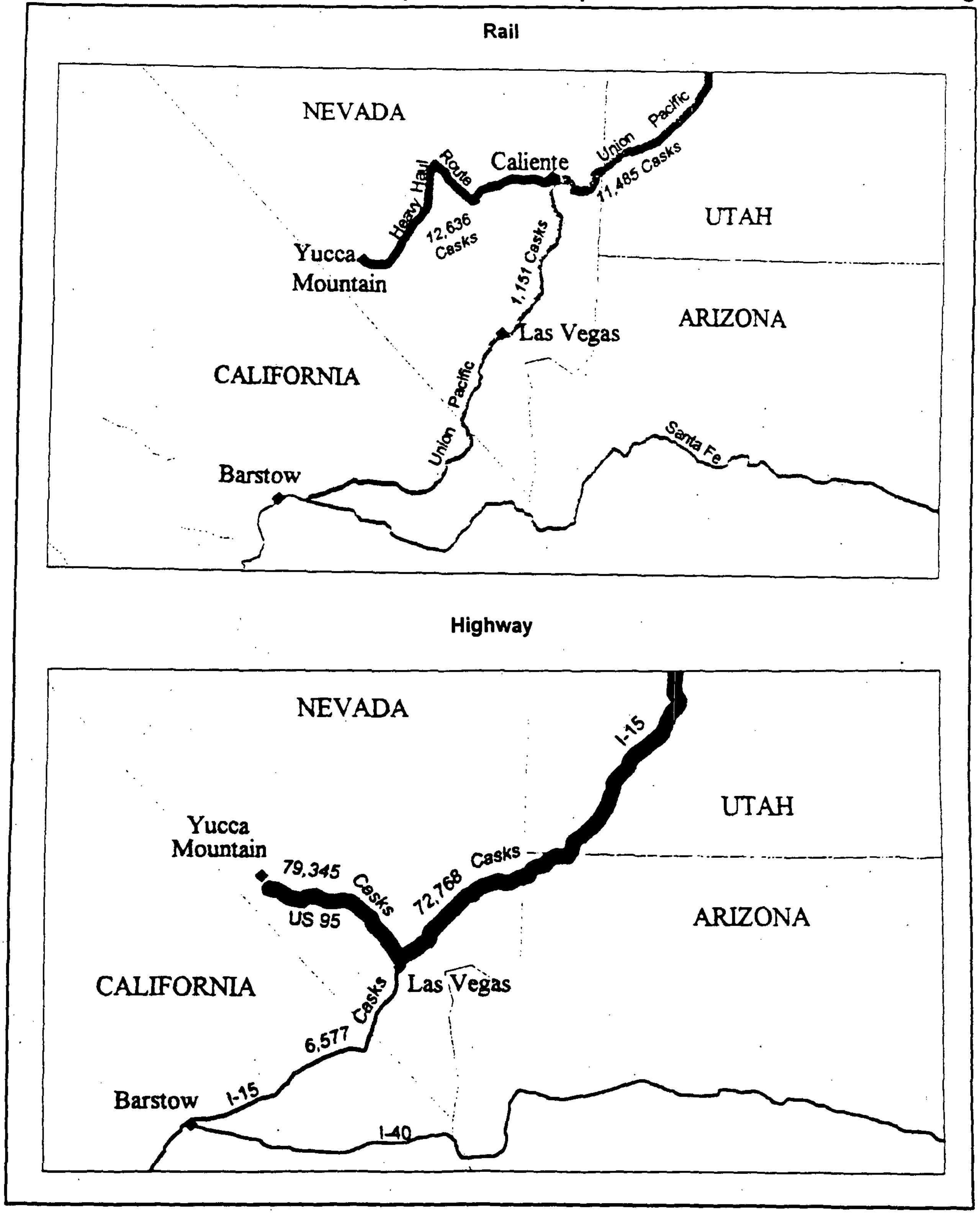


Figure 17-2. Life of Operations Rail & Highway Shipments in Southern NV Region MPC Base Case Choices/Default Routing

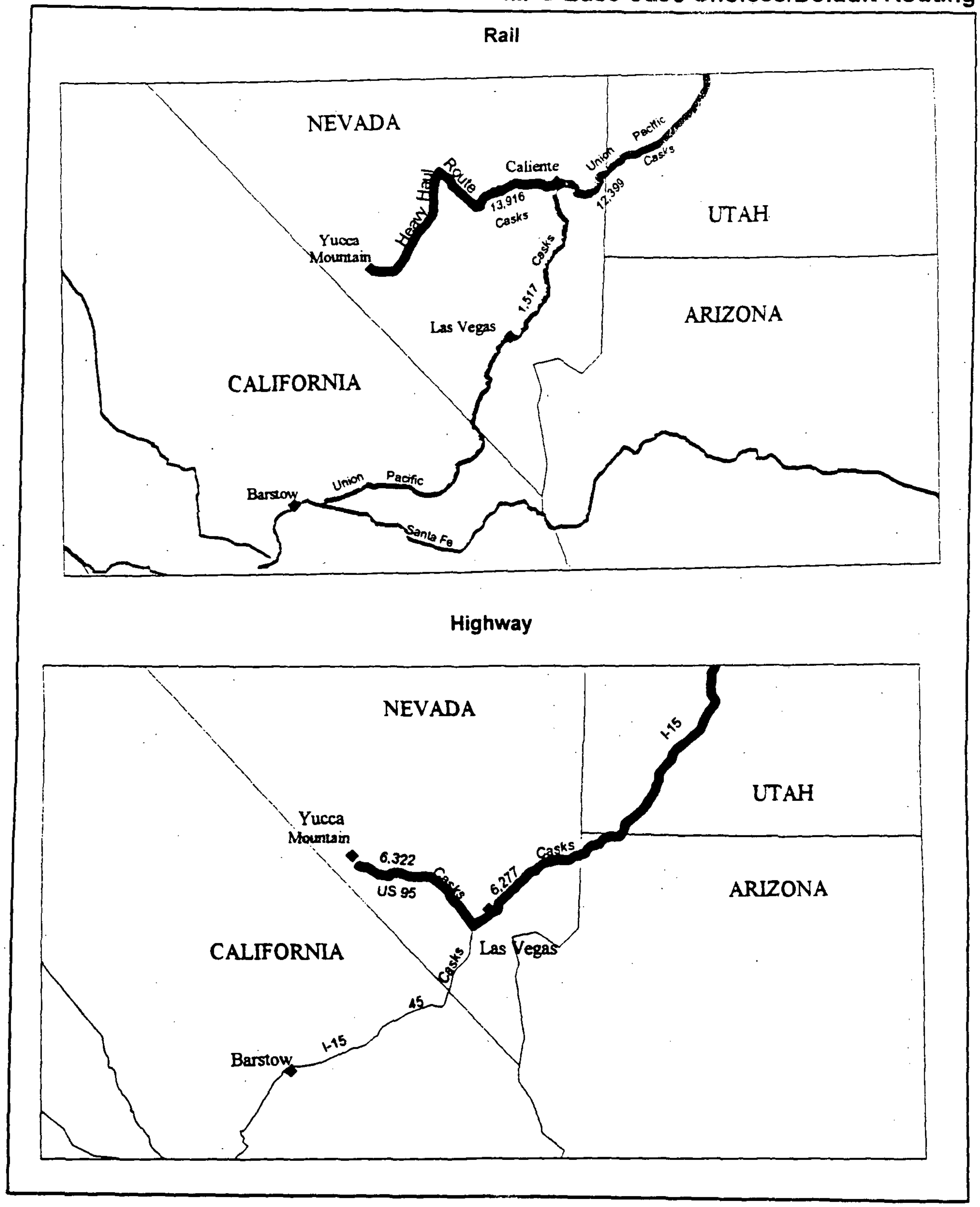
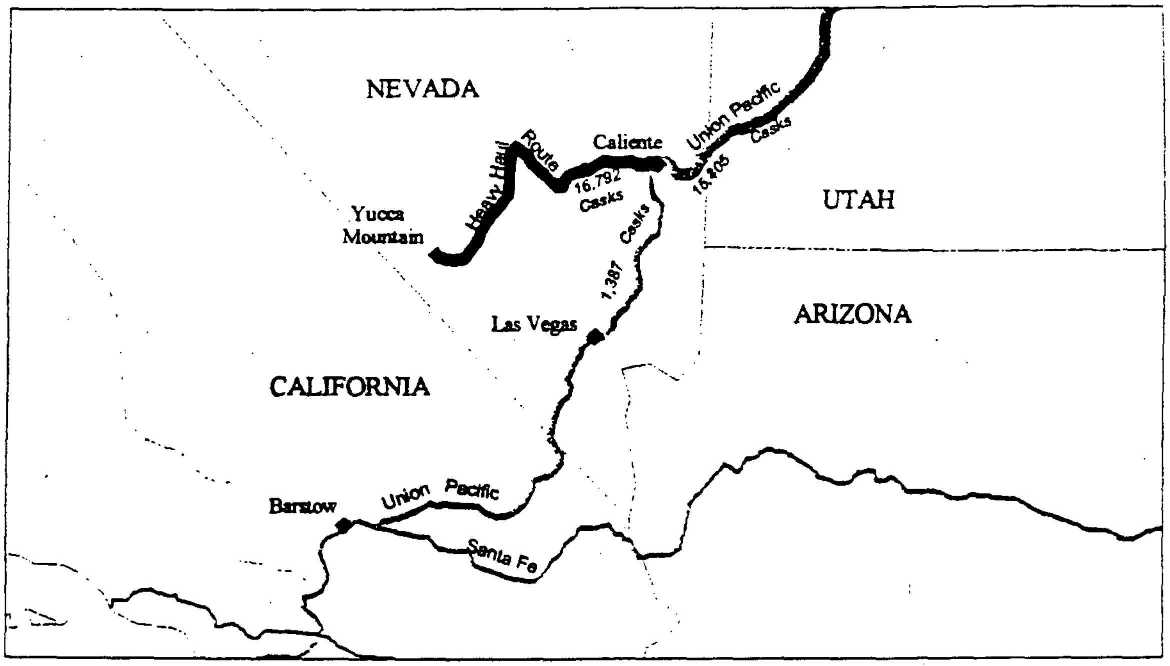
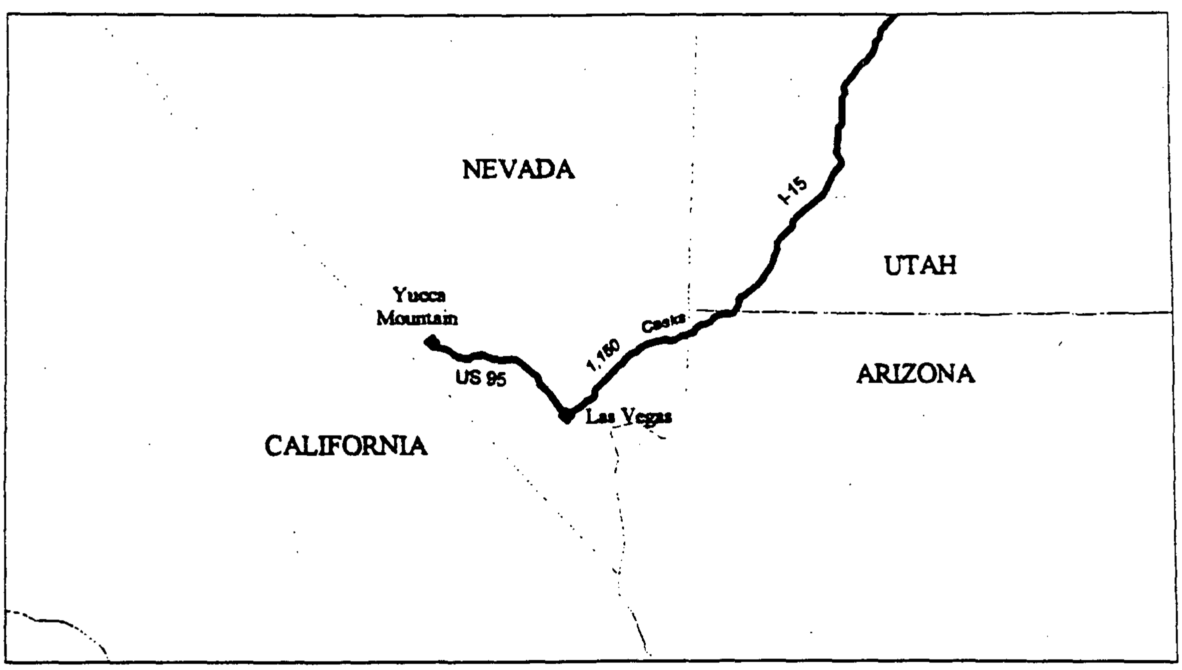


Figure 17-3. Life of Operations Rail & Highway Shipments in Southern NV Region Maximum Rail Transportation Choices/Default Routing

Rail



Highway



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18. REGIONAL ROUTING ALTERNATIVES

The maps presented in Section 16 can be viewed from many different national, regional, or local perspectives. National perspectives may involve the overall safety or cost efficiency of the national shipment campaign, while regional perspectives may seek to limit impacts on certain centers of population and commerce, and local perspectives may focus on certain facilities (e.g., a hospital or elementary school) or route conditions (e.g., a hazardous interchange) or special events (e.g., the upcoming winter Olympics in Salt Lake City). Under HM164, for example, states may choose to designate alternative routes for shipment of "highway route controlled quantities" of hazardous materials, including SNF and HLW. In a national shipment campaign, such designations have system effects which require coordination with "upstream" and "downstream" states. Rail routes are generally determined by rail carriers, in negotiation with utility shippers and DOE. But the choice to heavy-haul to one railhead rather than another at the origin site, or changes in railroad ownership, can substantially alter a 2,000 mile cross-country route.

The use of Interstate 43, which extends south from Green Bay through Milwaukee and southwest to Beloit, WI provides an example of possible regional perspectives on the routing of SNF shipments. In the current capabilities scenario, I-43 is used to move wastes away from the Kewaunee and Point Beach sites in Wisconsin. In northern Illinois, where the Byron and Zion plants are located, I-43 connects to I-80 via I-39 in Rockford and I-88 in Moline, However, since Byron and Zion ship by rail in the current capabilities scenario, the connecting segments in Illinois are used only by shipments originating in Wisconsin. These circumstances, which are just one example of hundreds involved in a national shipment campaign, could affect the perspective of various state agencies and local communities in Wisconsin and Illinois.

Consolidated Southern Routing

A major alternative to the default routing criteria reflected in the results presented in Sections 16 and 17, is a "consolidated southern" option which would concentrate cross-country rail shipments on the Santa Fe rail line rather than the Union Pacific and Southern Pacific, and concentrate cross-country highway shipments on I-40 rather than I-80 or I-70. To illustrate the effects of regional routing alternatives, we have compared cask shipment estimates under default and consolidated southern routing options for five rail and five highway route segments in four states—Wyoming, Colorado, New Mexico, and Nevada (see Figures 18-1 through 18-3):

- The Wyoming route segments are along the Union Pacific line near Rawlins in south-central Wyoming, and along a nearby segment of I-80.

- The Colorado segments are along the Southern Pacific rail line near Glenwood Springs in western Colorado, and along a nearby segment of I-70.

- The New Mexico segments are along the Santa Fe rail line near Grants in northwestern New Mexico, and along a nearby segment of I-40.

Figure 18-1a. Life of Operations Rail and Highway Cask Shipments
Current Capabilities Transportation Choices/Default Routing

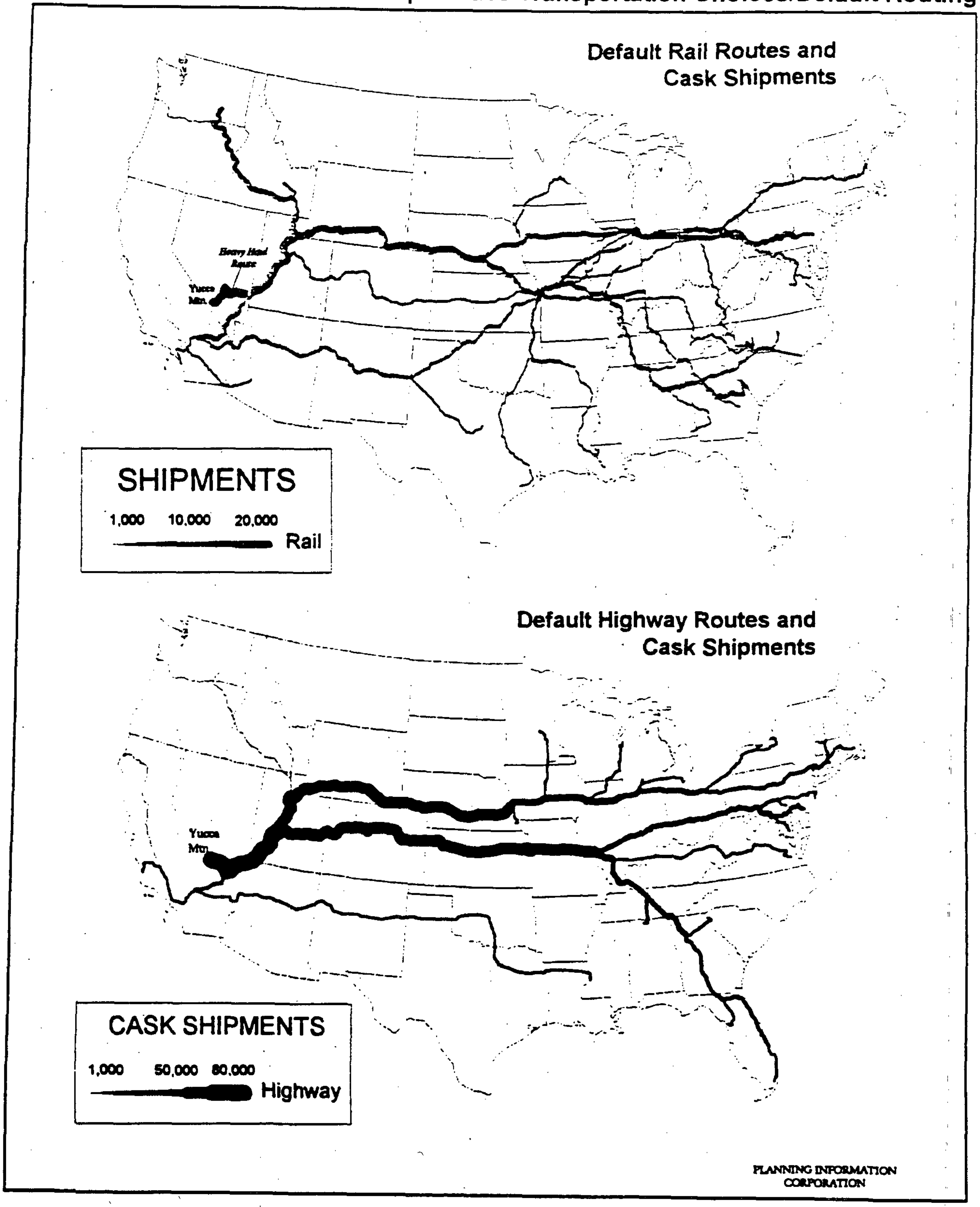


Figure 18-1b. Life of Operations Rail and Highway Cask Shipments Current Capabilities Transportation Choices/Consolidated Southern Routing

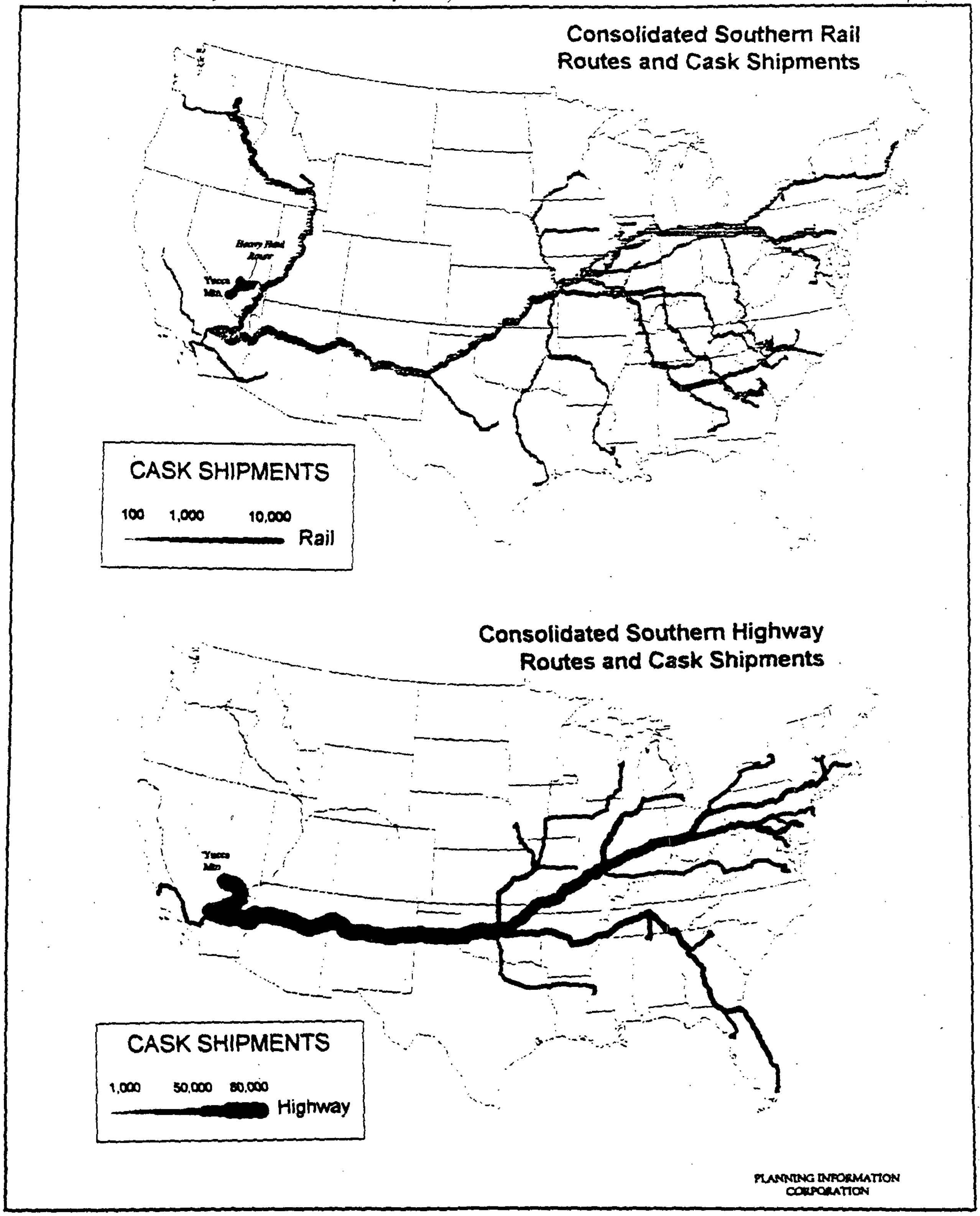
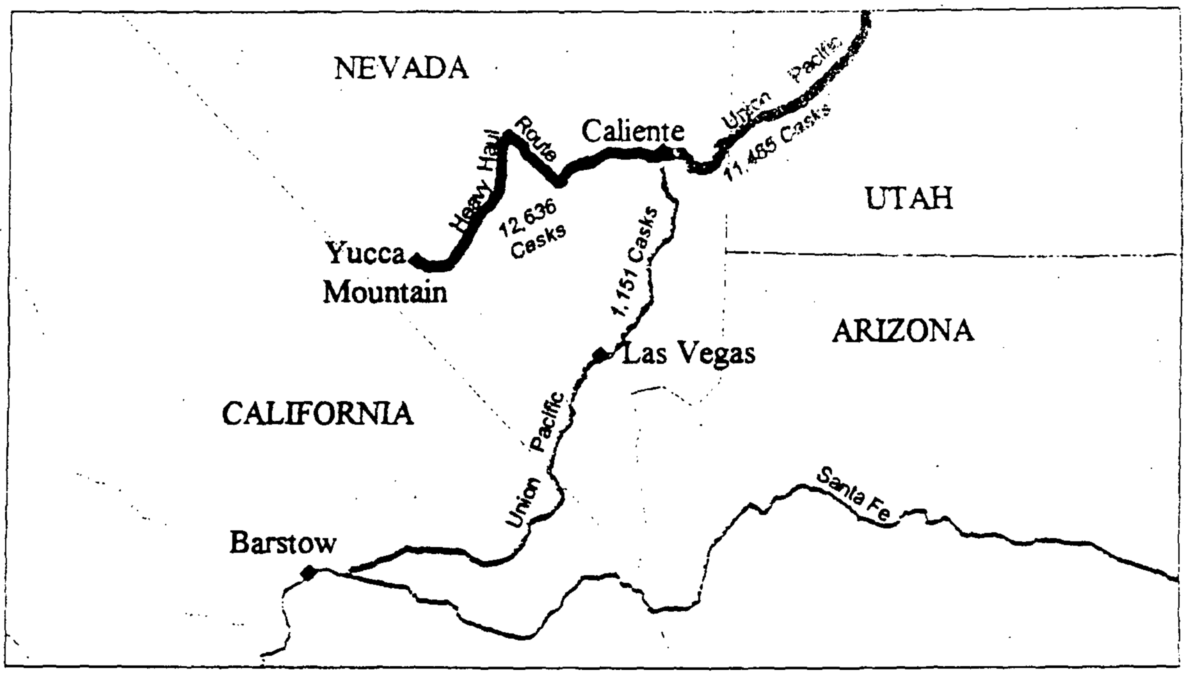


Figure 18-1a (NV). Life of Operations Rail and Highway Cask Shipments in (NV) Current Capabilities Transportation Choices/Default Routing

Rail



Highway

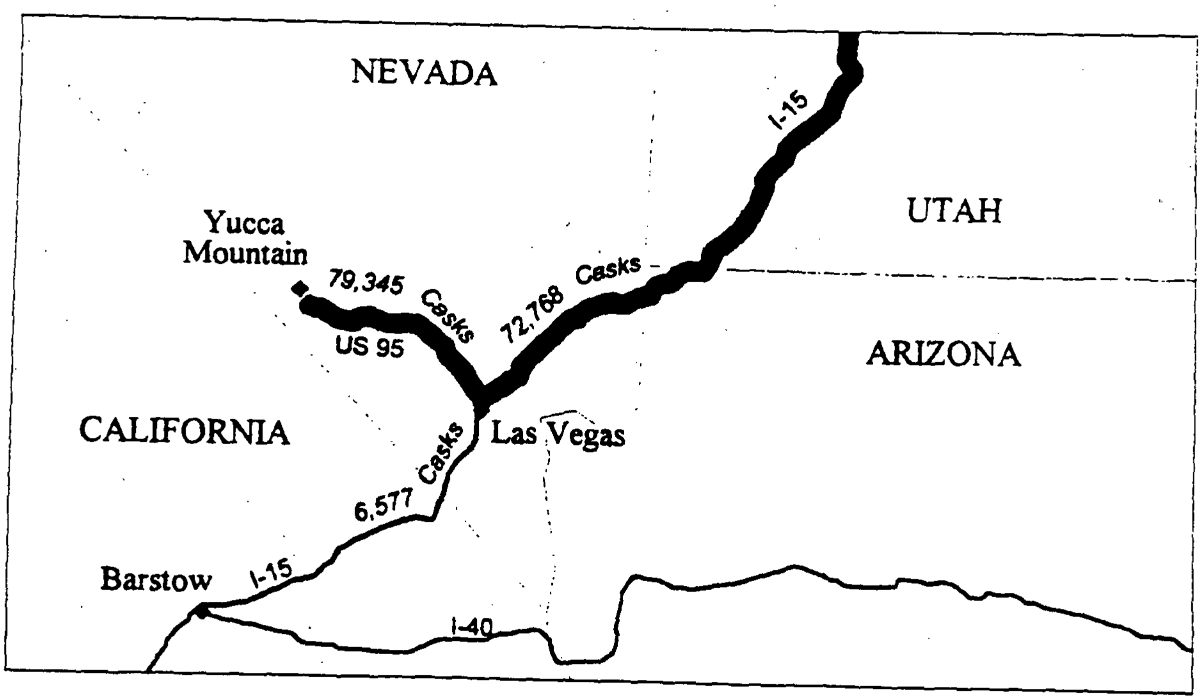
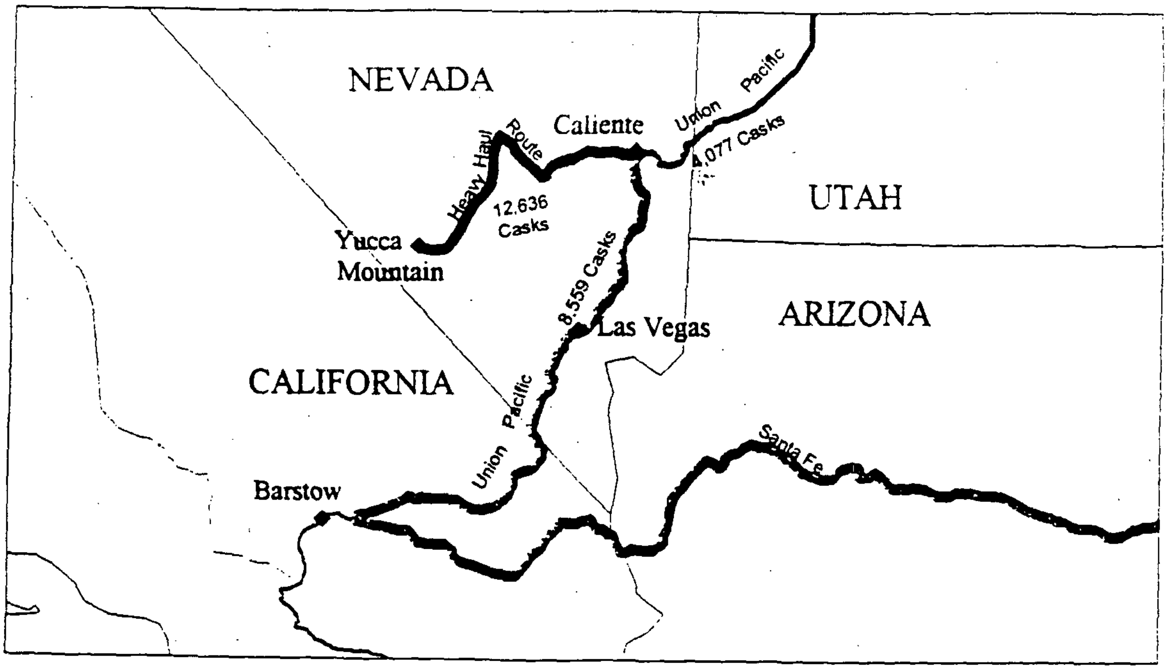


Figure 18-1b (NV). Life of Operations Rail and Highway Cask Shipments in (NV) Current Capabilities Transportation Choices/Consolidated Southern Routing

Rail



Highway

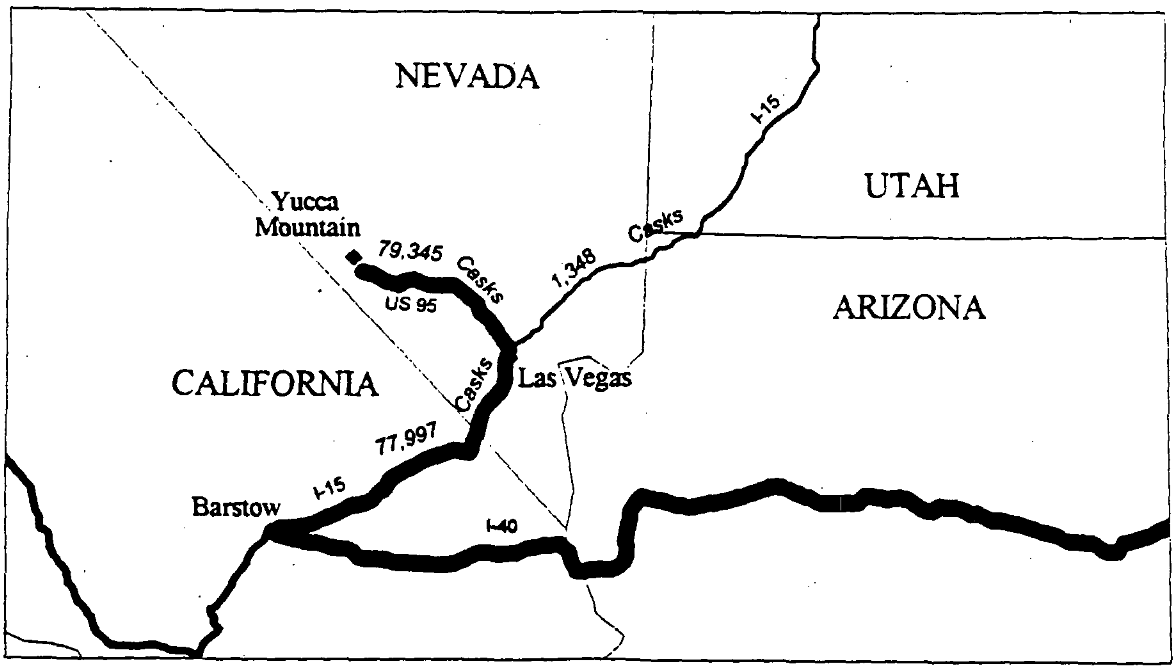


Figure 18-2a. Life of Operations Rail and Highway Cask Shipments
MPC Base Case Transportation Choices/Default Routing

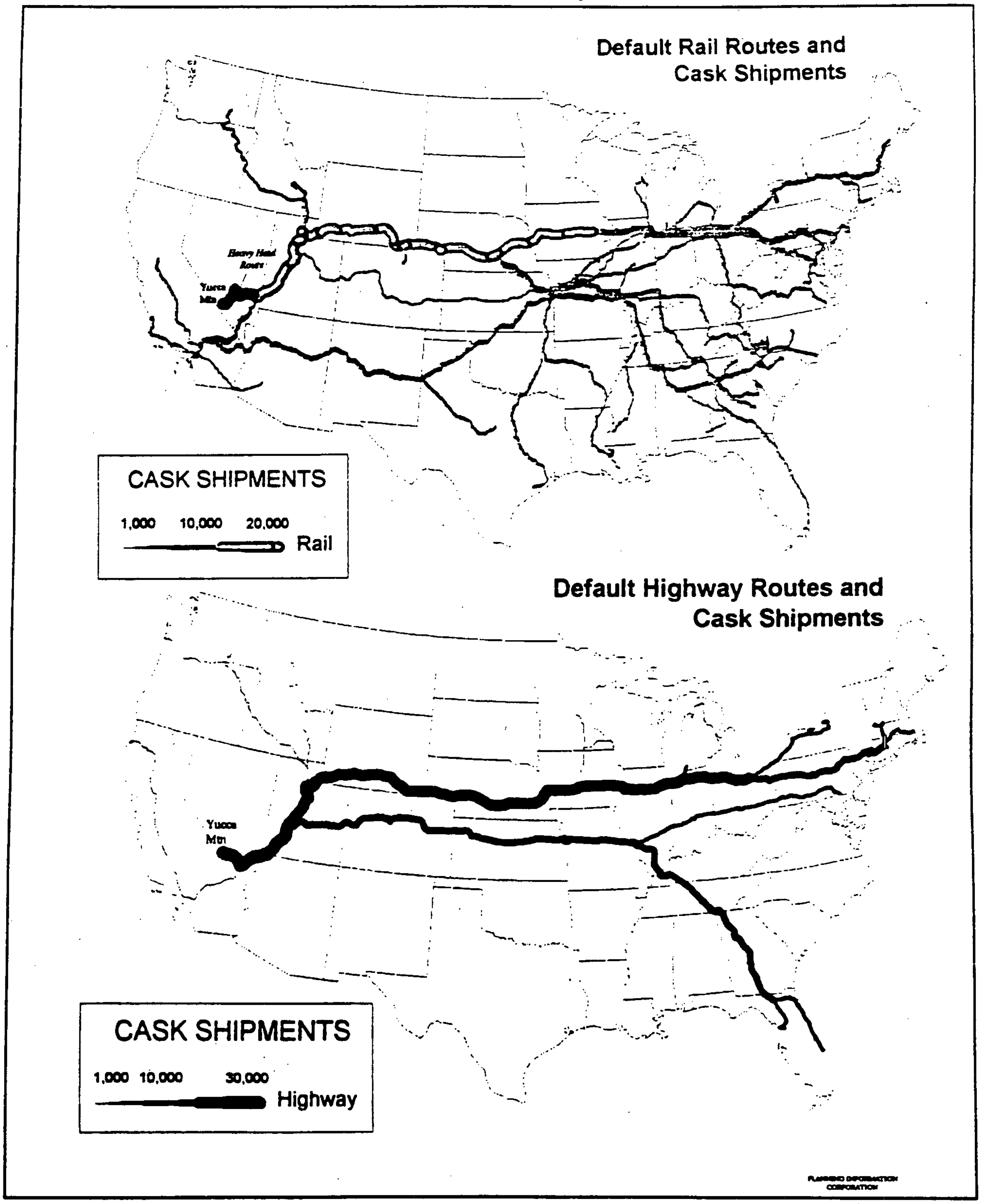


Figure 18-2b. Life of Operations Rail and Highway Cask Shipments
MPC Base Case Transportation Choices/Consolidated Southern Routing

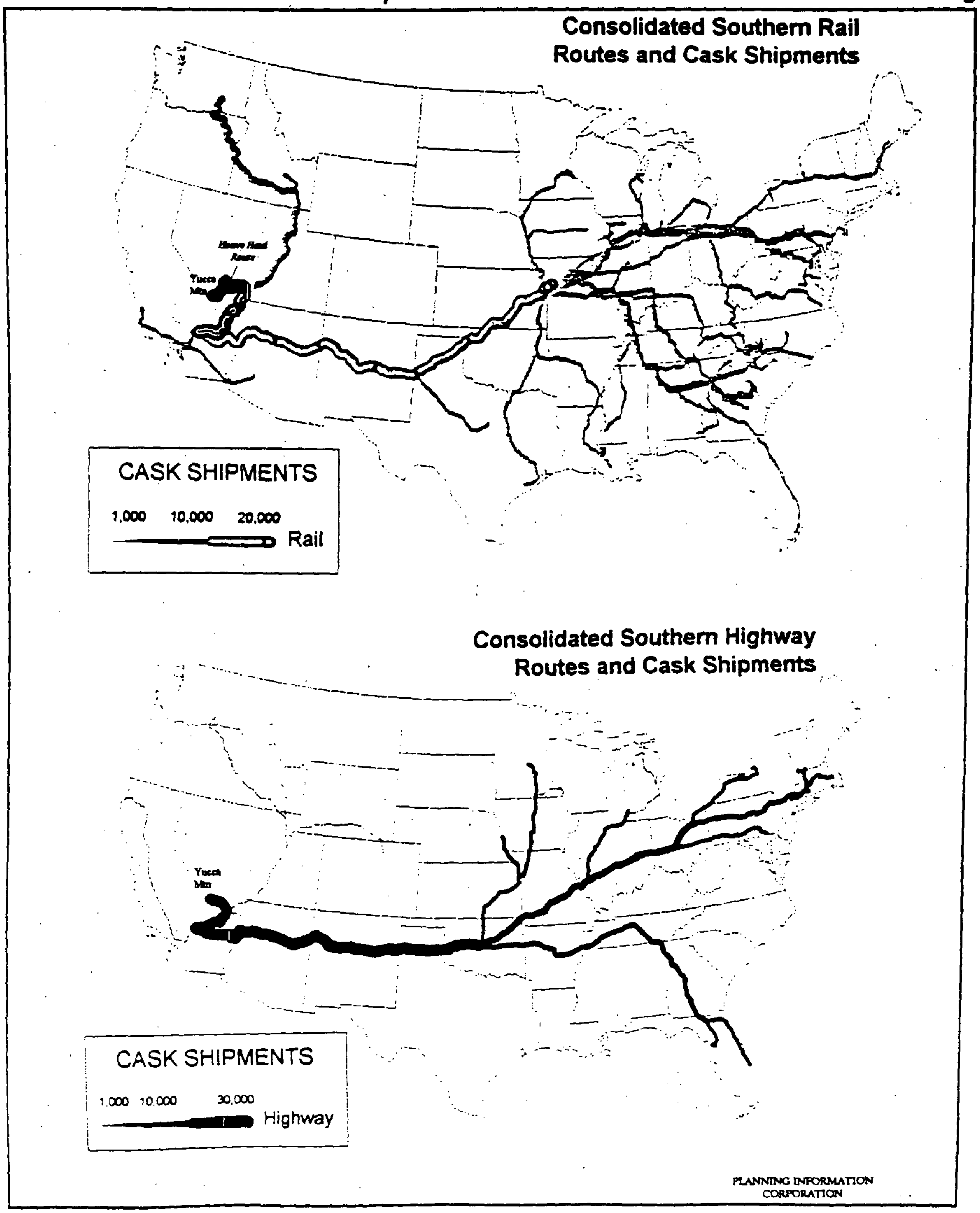


**Figure 18-2a (NV). Life of Operations Rail and Highway Cask Shipments in (NV)
MPC Base Case Transportation Choices/Default Routing**

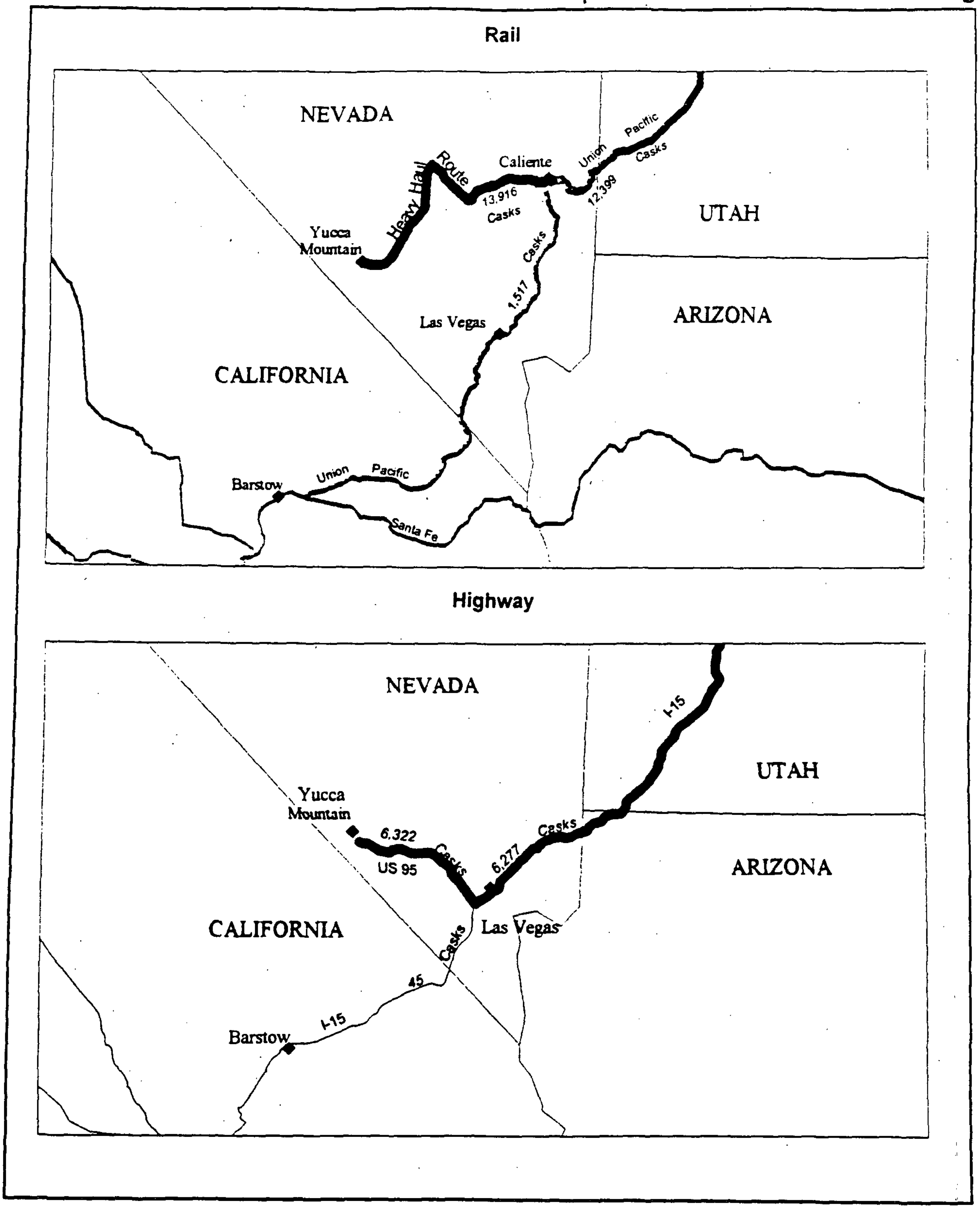


Figure 18-2b (NV). Life of Operations Rail and Highway Cask Shipments in (NV) MPC Base Case Transportation Choices/Consolidated Southern Routing

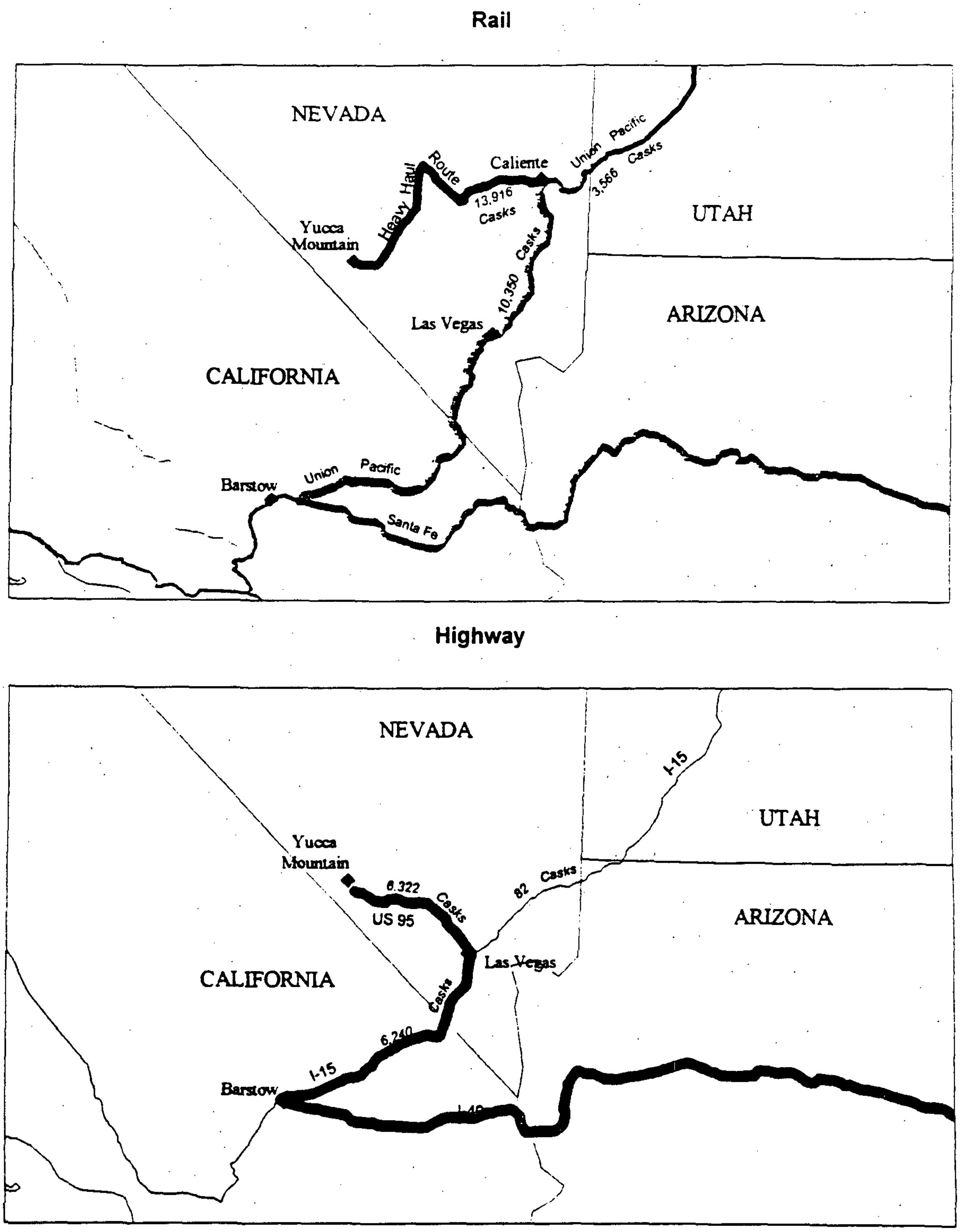


**Figure 18-3a. Life of Operations Rail and Highway Cask Shipments
Maximum Rail Transportation Choices/Default Routing**

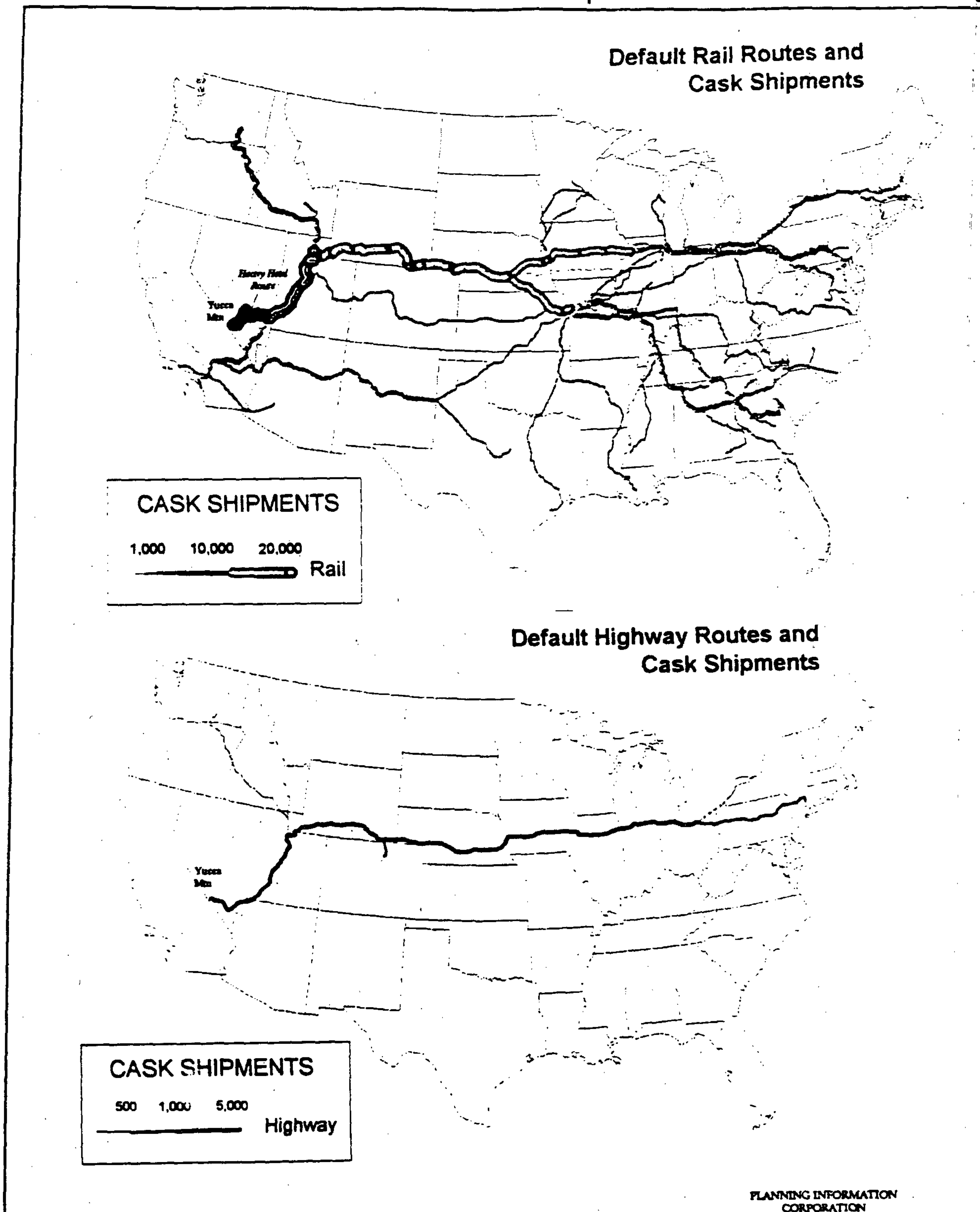


Figure 18-3b. Life of Operations Rail and Highway Cask Shipments
Maximum Rail Transportation Choices/Consolidated Southern Routing

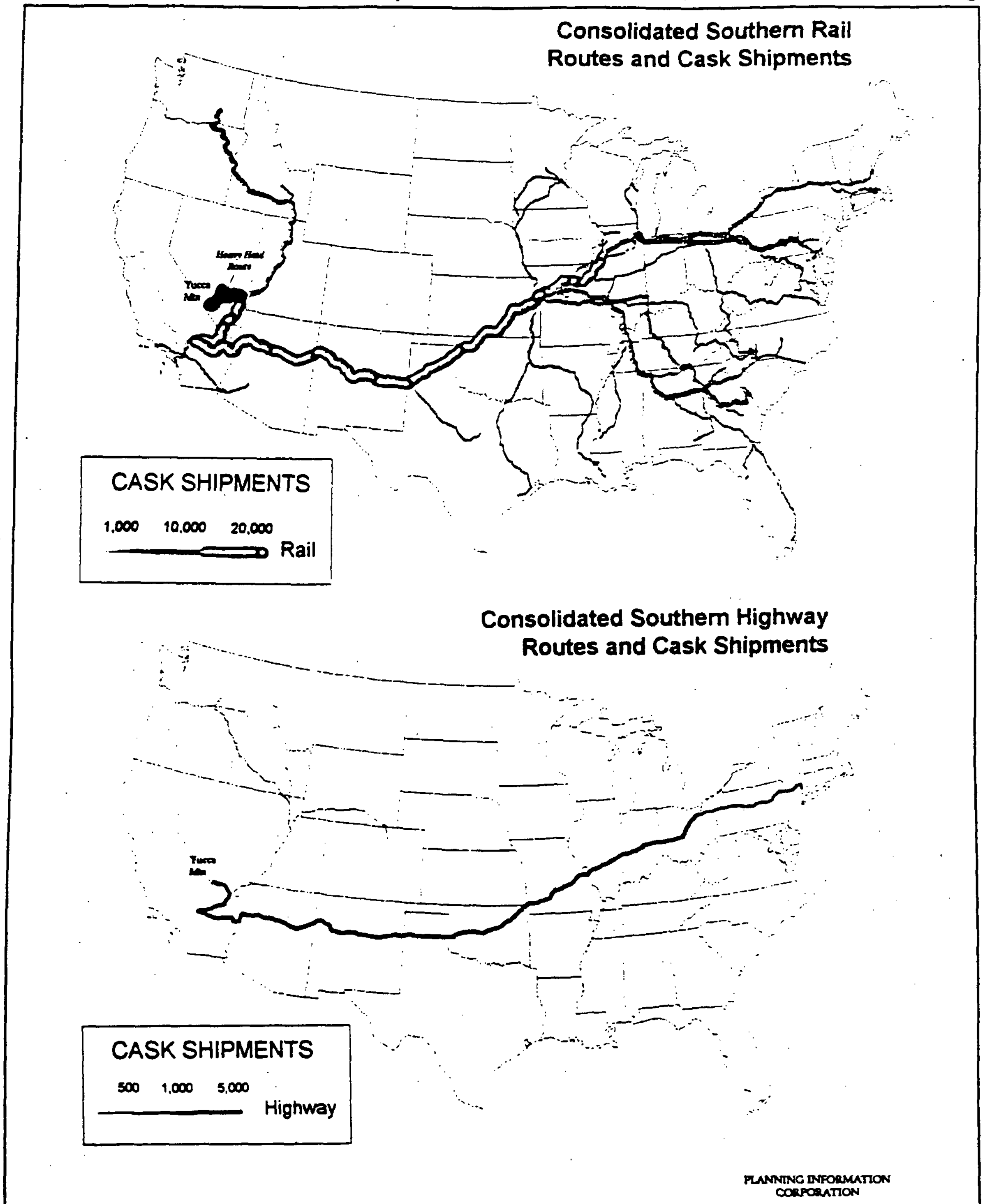
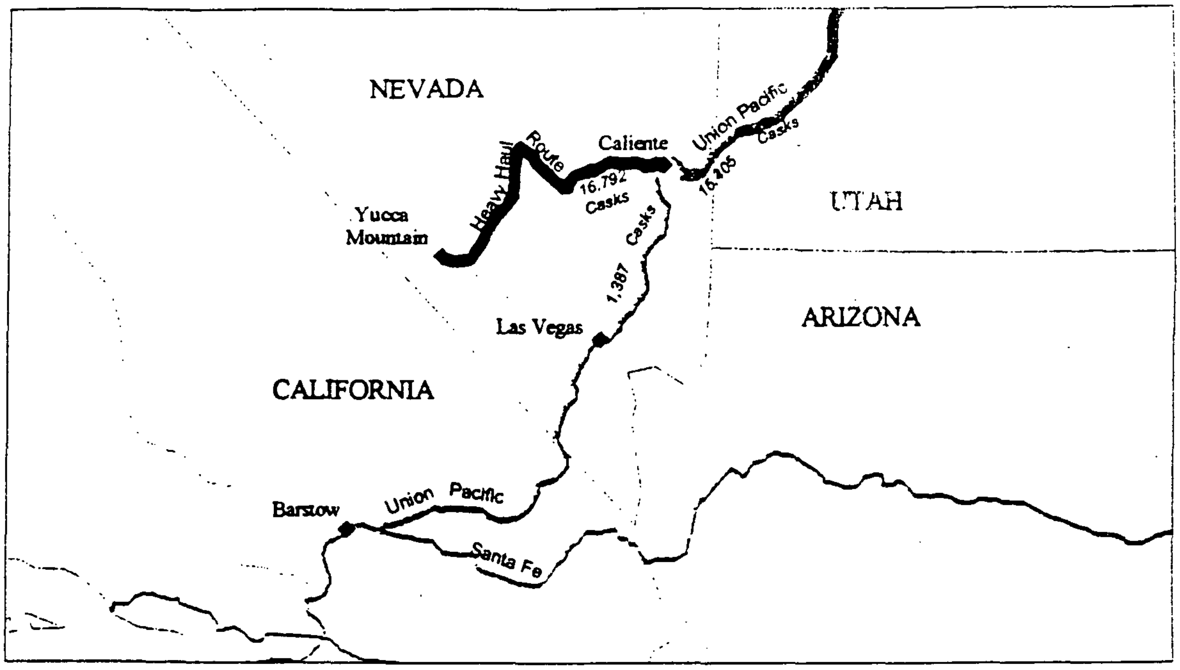


Figure 18-3a (NV). Life of Operations Rail and Highway Cask Shipments in (NV) Maximum Rail Transportation Choices/Default Routing

Rail



Highway

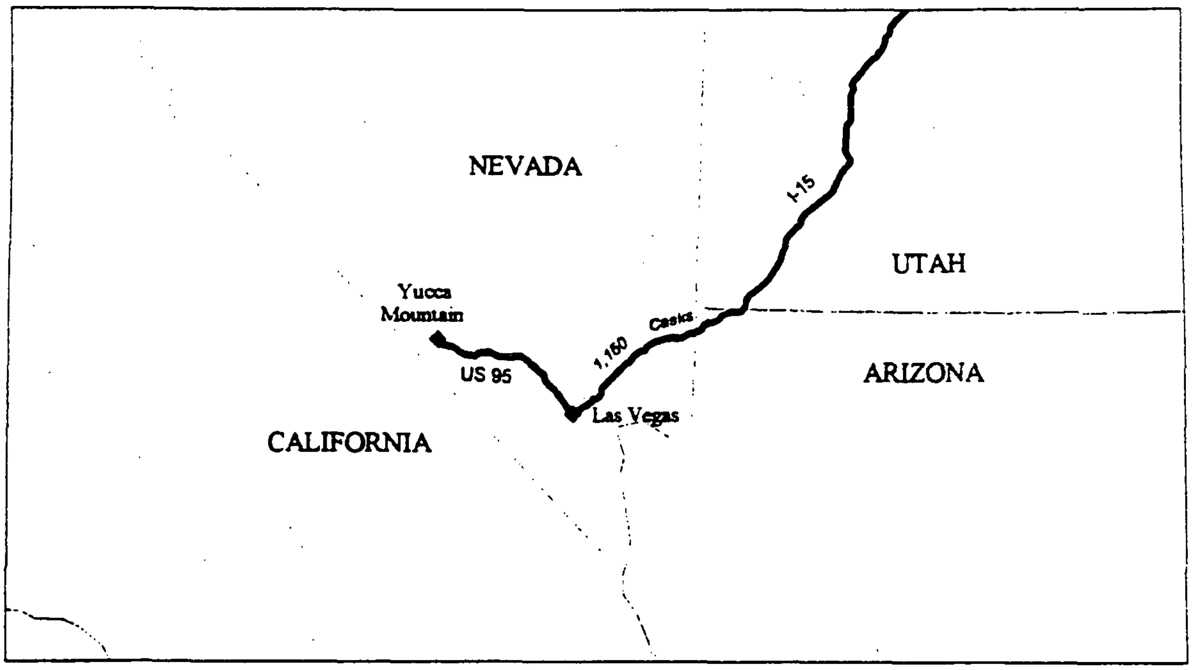
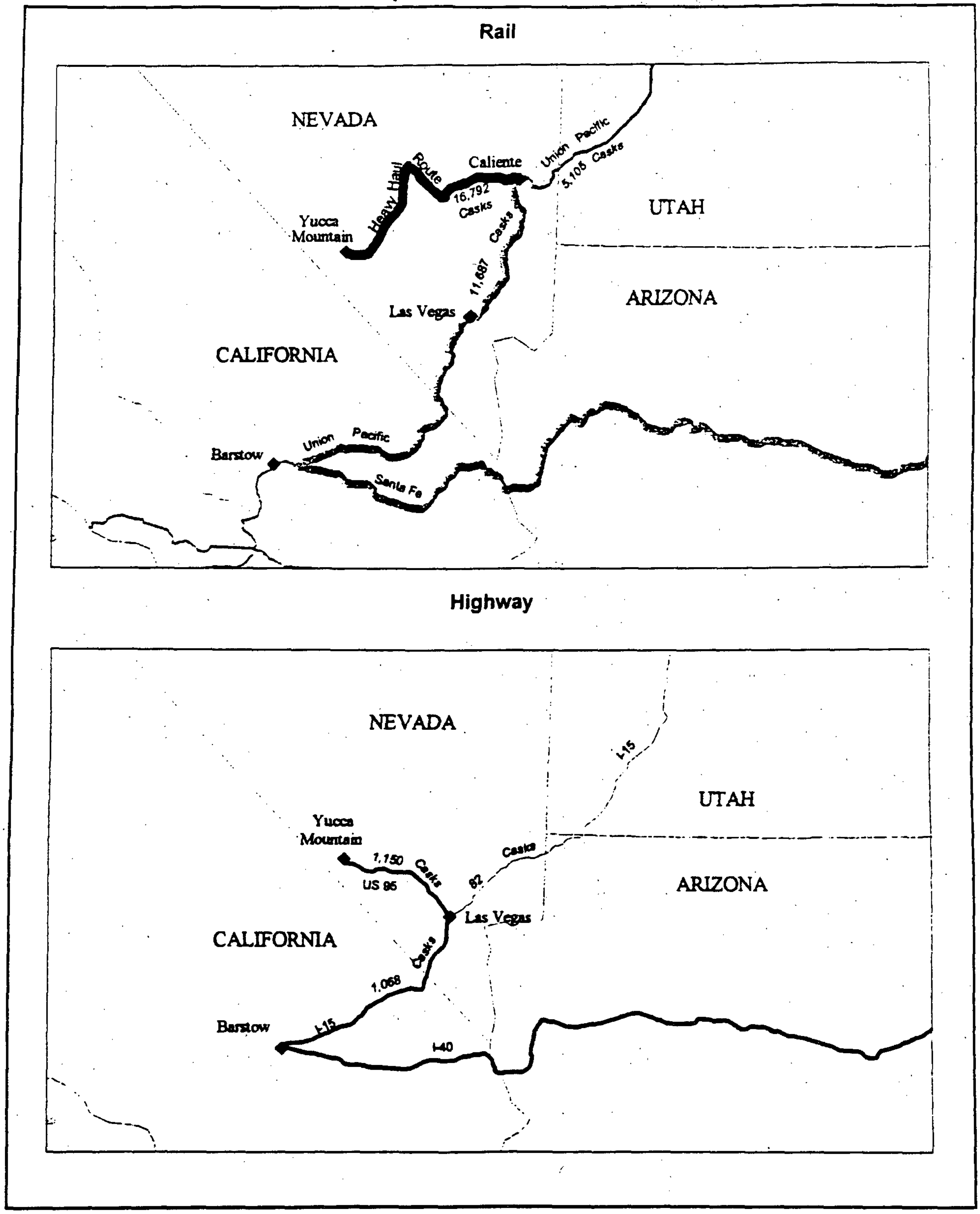


Figure 18-3b (NV). Life of Operations Rail and Highway Cask Shipments in (NV) Maximum Rail Transportation Choices/Consolidated Southern Routing



- One pair of Nevada segments are the Union Pacific line and a segment of I-15 near the Las Vegas Strip. A second pair of Nevada segments are the Union Pacific rail line near the Utah-Nevada border, and a segment of I-15 as it crosses the Moapa Indian Reservation northeast of Las Vegas.

Under all three scenarios of transportation choices (as indicated in Table 18-1), consolidated southern routing would eliminate rail and highway shipments through Wyoming and Colorado, and substantially reduce rail and highway shipments from Utah into Nevada. At the same time, however, consolidated southern routing would substantially increase rail and highway shipments through New Mexico, through California east of Barstow and into Nevada along the Las Vegas Strip. Though not presented in table 17-1, consolidated southern routing has effects further east in the national routing system for SNF and HLW—e.g., in Chicago, Kansas City, and St. Louis. Other routing options would also have systems effects, increasing rail or highway shipments through certain communities, and reducing shipments through others.

Table 18-1. Life of Operations Rail and Highway Cask Shipments Default and Consolidated Southern Routing 5 Rail and 5 Highway Cask Segments

	CURRENT CAPABILITIES			MPC BASE CASE			MAXIMUM RAIL		
	Default Routing	Consol So. Rtg	Change	Default Routing	Consol So. Rtg	Change	Default Routing	Consol So. Rtg	Change
Rail Segments:									
Wyo: UP	8286	0	-8286	9315	0	-9315	11114	0	-11114
Col: SP	362	0	-362	79	0	-79	214	0	-214
NV: UP @ UT line	11485	4077	-7408	12399	3566	-8833	15405	5105	-10300
NM: SF	770	9418	8648	808	10202	9394	631	11959	11328
NV: UP @ LV Strip	1151	8559	7408	1517	10360	8843	1387	11687	10300
Hwy Segments:									
Wyo: I-80	31109	54	-31055	14319	10	-14309	1083	10	-1073
Col: I-70	39496	0	-39496	9877	0	-9877	0	0	0
NV: I-15 @ Moapa	72768	1348	-71420	6277	82	-6195	1150	82	-1068
NM: I-40	3630	74181	70551	0	24186	24186	0	1073	1073
NV: I-15 @ Strip	6577	77997	71420	45	6240	6195	0	1068	1068

19. THE NATIONAL SHIPMENT CAMPAIGN: ANNUAL SHIPMENTS

What are the annual impacts of the national shipment campaign for the nation's network of major railroads and highways? Do the impacts vary from year 1 to year 2, or 3, for example, or from year 1 to year 10 to year 20? These questions are relevant to the planning and management of a national shipment campaign. For example, DOE's May 28, 1996 notice regarding the acquisition of transportation services indicates (pg. 1) that "Initially, spent-fuel delivered to the Federal site would be canistered. . .but at some point*. . . the contractor may be required to handle uncanistered spent-fuel." What modifications in the oldest-fuel-first prioritization for spent fuel acceptance and pickup (see Section 5) would be necessary to limit pickup to canistered fuel in the first two acceptance years?

Another concern is the preparedness of state, local, and tribal officials to manage risk and respond to emergencies associated with SNF and HLW shipments. Compounding this concern is the current Congressional intent to accelerate the first shipments of SNF and HLW, perhaps as early as 1998 or 1999. Further complicating the planning process are the initiatives to privatize the transportation process, through a series of contracts with regional servicing agents (RSAs). Finally, many analysts share the belief that the number of shipments should be reduced by using higher-volume rail and truck containers that are yet to be developed or licensed, and by improvements to waste-handling infrastructure that could be expensive to complete.

The scenarios developed for this assessment reveal significant differences between the overall campaign and its initial shipment years. In the current capabilities scenario, for example, about 35 percent of the MTU would be shipped by truck, a percentage which increases to 66 percent in the initial three shipment years. In the MPC base case scenario of transportation choices, about 11 percent of total MTU would be shipped by truck, a percentage which increases to 27 percent in the initial three shipment years—even more if improvements in loading capacity and/or near-site infrastructure were not implemented with casks available for the startup of the shipment campaign.

Figures 18-1, 18-2 and 18-3 present origin sites and affected rail and highway routes (default routing) under the current capabilities scenario of transportation choices in years 1, 2, and 3 of the prospective shipment campaign. While it is possible that the special arrangements and improvements implied by the MPC base case and maximum rail scenarios could be implemented by year 1, it can also be argued that the current capabilities are likely to be operative in the initial years, regardless of the strategy for the overall shipment campaign.

Figures 18-4 and 18-5 present origin sites and affected rail and highway routes (default routing) in year 20 of the prospective shipment campaign—in this case comparing affected routes and cask shipments under the current capabilities and maximum rail scenarios of transportation choices.

* RSA Phase C contract years 3-5 (see "Timing of RSA Phases": VU-Graph Presentations for July 9, 1996 Presolicitation Conference, ref 2).

Year 1 Routes and Cask Shipments

Figure 19-1 shows the likely pattern of shipments comprising the 1,200 MTU first-year requirement of S. 1936, assuming the oldest-fuel-first priority acceptance ranking described above. The default routing is essentially unconstrained, as might be developed by an RSA or by DOE contract carriers. Shipments would be made from 8 sites with rail access and 20 sites with truck-only access:

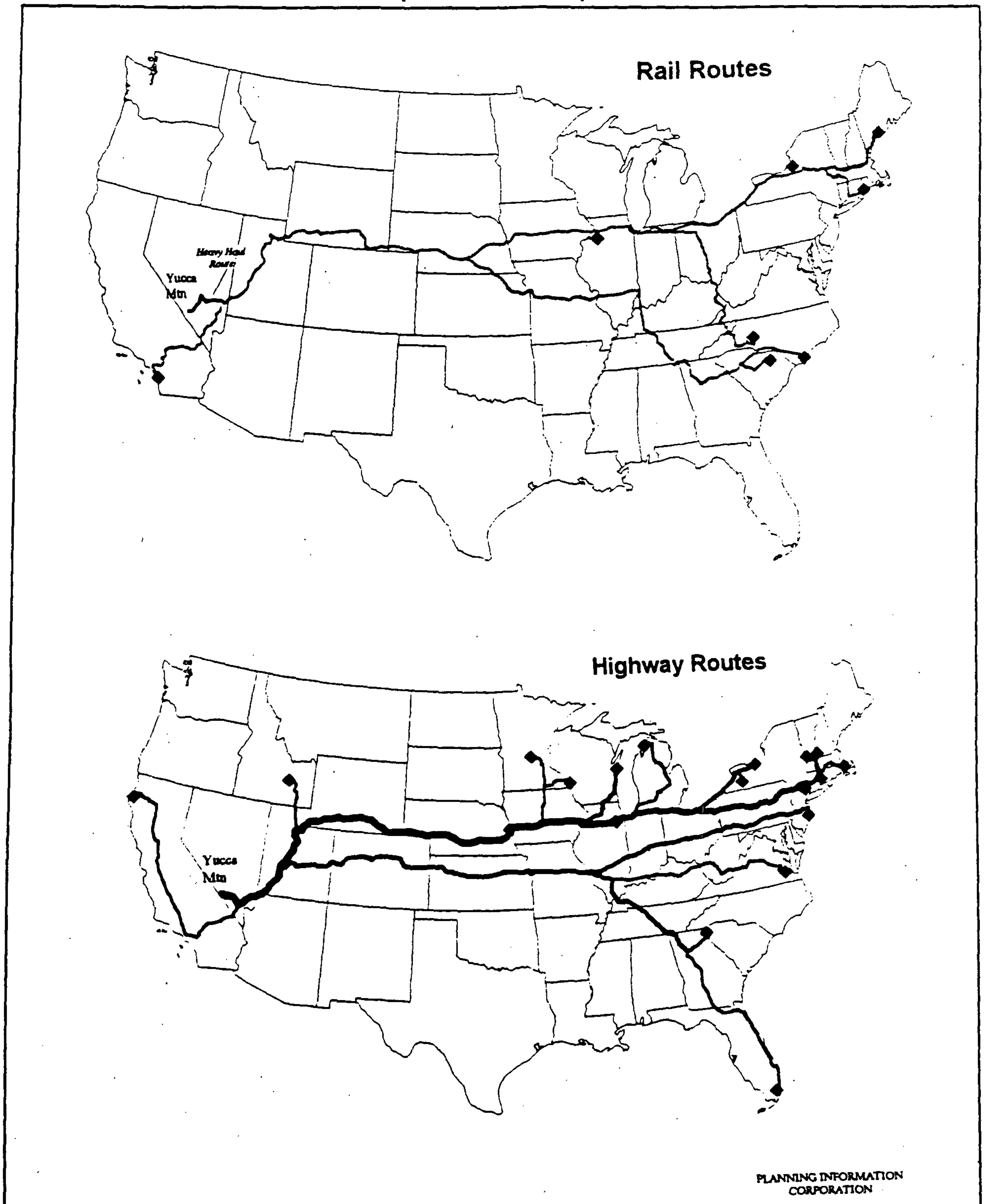
Rail Shipments

Origin	Casks
CA: San Onofre	2
CT: Millstone	12
IL: Quad Cities	7
NC: Brunswick	14
NC: McGuire	2
ME: Maine Yankee	11
NY: Nine Mile Point	15
SC: Robinson	1
TOTAL	64

Truck Shipments

Origin	Casks
CA: Humboldt Bay	87
CT: Haddam Neck	131
FL: Turkey Point	90
ID: INEL	6
IL: Braidwood	9
IL: Dresden	344
IL: Morris	755
MA: Pilgrim	10
MA: Yankee Rowe	73
MI: Big Rock Point	9
MN: Monticello	12
NE: Ft. Calhoun	25
NJ: Oyster Creek	246
NY: Ginna	118
NY: Indian Point	160
NY: West Valley	83
SC: Oconee	35
VA: Surry	44
VT: Vermont Yankee	189
WI: LaCrosse	28
WI: Point Beach	151
TOTAL	2,605

Figure 19-1. Year 1 Cask Shipments by Route and Origin
Current Capabilities Transportation Choices/Default Routing



Year 2 Routes and Cask Shipments

In the second year, the shipment schedule shows an increased number of shipment origin sites (13 railroad, 24 truck), as shown in Figure 19-2. The weight of SNF is the same as in year 2 (at least 1,200 MTU) and the number of casks is somewhat lower than year 1:

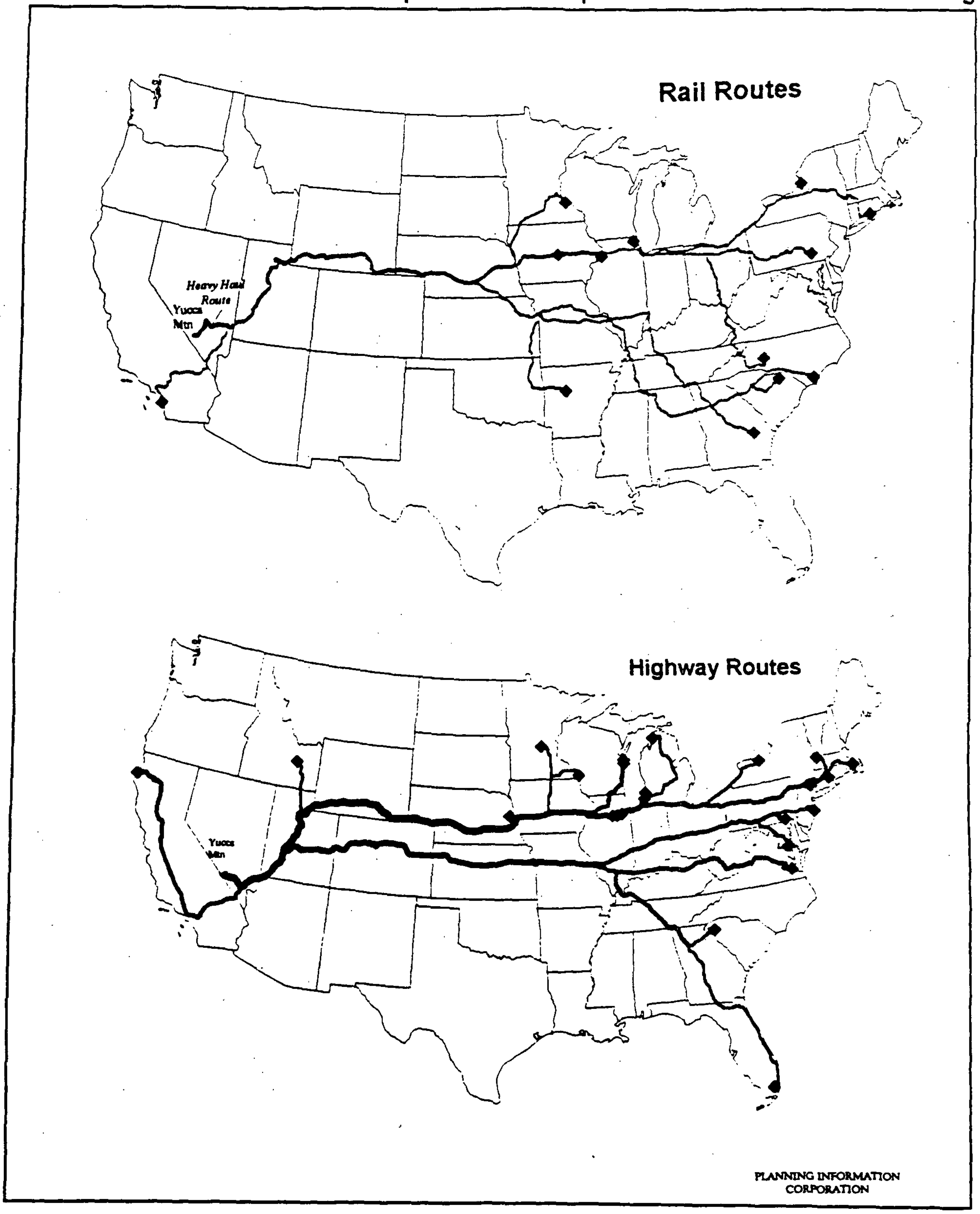
Rail Shipments

Origin	Casks
AR: Arkansas Nuclear	5
CA: San Onofre	2
CT: Millstone	13
GA: Hatch	1
IA: Duane Arnold	8
IL: Quad Cities	21
IL: Zion	9
MN: Prairie Island	6
NC: Brunswick	10
NC: McGuire	9
NY: Nine Mile Point	18
PA: Three Mile Island	3
SC: Robinson	1
TOTAL	106

Truck Shipments

Origin	Casks
CA: Humboldt Bay	109
CT: Haddam Neck	101
FL: Turkey Point	95
ID: INEL	17
IL: Braidwood	11
IL: Dresden	184
IL: Morris	235
MA: Pilgrim	66
MA: Yankee Rowe	40
MD: Calvert Cliffs	32
MI: Big Rock Point	11
MI: Cook	63
MI: Palisades	205
MN: Monticello	13
NE: Ft. Calhoun	36
NJ: Oyster Creek	28
NY: Ginna	37
NY: Indian Point	72
PA: Peach Bottom	187
SC: Oconee	26
VA: Surry	226
WI: Kewaunee	56
WI: LaCrosse	13
WI: Point Beach	119
TOTAL	1,982

Figure 19-2. Year 2 Cask Shipments by Route and Origin
Current Capabilities Transportation Choices/Default Routing



Year 3 Routes and Cask Shipments

In year three, the volume of shipment increases from 1,200 to 2,000 MTU, increasing both the number of casks and the number of shipment sites (18 rail and 27 truck), as shown in Figure 19-3. However, we still assume the current capabilities scenario and unconstrained routing.

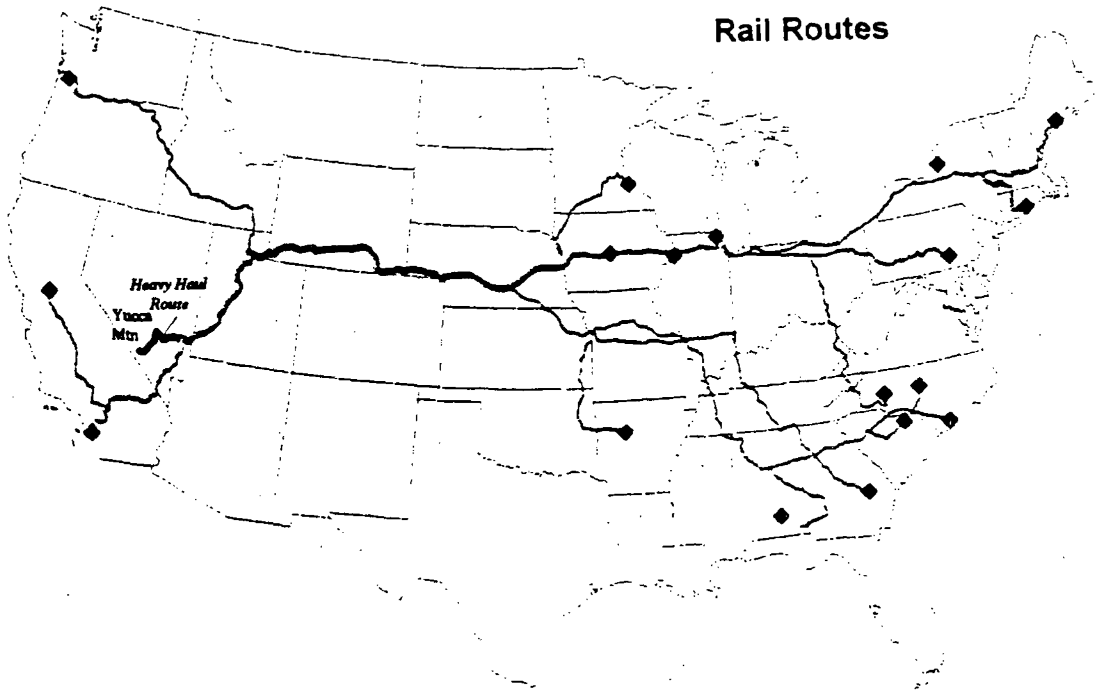
Rail Shipments

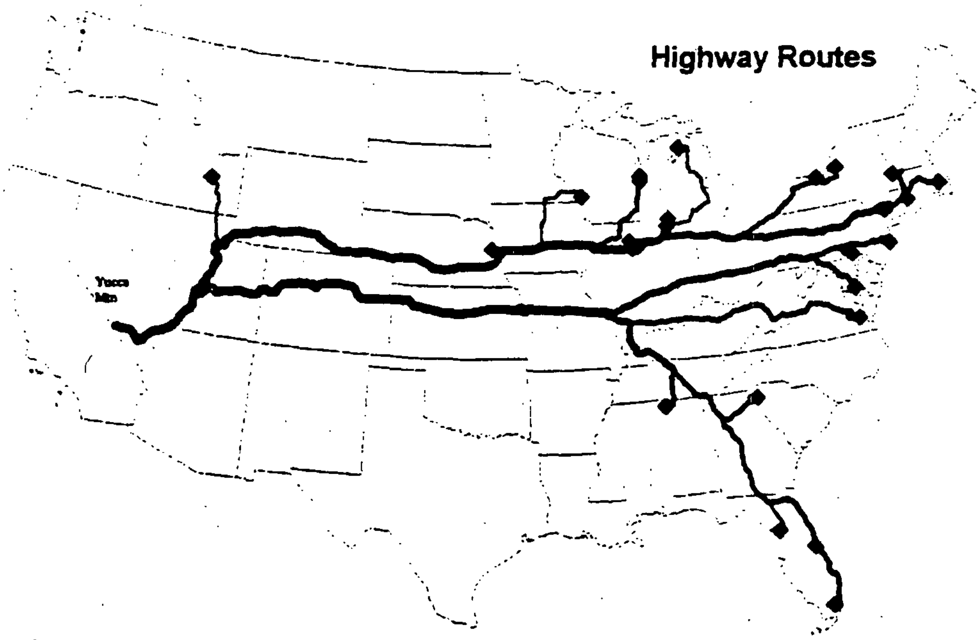
Origin	Casks
AL: Farley	3
AR: Arkansas Nuclear	6
CA: Rancho Seco	7
CA: San Onofre	2
CT: Millstone	22
GA: Hatch	1
IA: Duane Arnold	6
IL: Quad Cities	27
IL: Zion	17
ME: Maine Yankee	10
MN: Prairie Island	6
NC: Brunswick	17
NC: Harris	6
NC: McGuire	16
NY: Nine Mile Point	8
OR: Trojan	1
PA: Three Mile Island	15
SC: Robinson	1
TOTAL	171

Truck Shipments

Origin	Casks
AL: Browns Ferry	165
CT: Haddam Neck	100
FL: Crystal River	2
FL: St. Lucie	52
FL: Turkey Point	151
ID: INEL	31
IL: Braidwood	23
IL: Dresden	451
IL: Morris	68
MA: Pilgrim	214
MA: Yankee Rowe	76
MD: Calvert Cliffs	184
MI: Big Rock Point	23
MI: Cook	64
MI: Palisades	68
NE: Ft. Calhoun	96
NJ: Oyster Creek	148
NY: FitzPatrick	134
NY: Ginna	122
NY: Indian Point	124
PA: Peach Bottom	342
SC: Oconee	215
VA: Surry	165
VT: Vermont Yankee	109
WI: Kewaunee	41
WI: LaCrosse	16
WI: Point Beach	125
TOTAL	3,309

Figure 19-3. Year 3 Cask Shipments by Route and Origin Current Capabilities Transportation Choices/Default Routing





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Year 20 Routes and Cask Shipments

After several years, it is possible that the utilities and RSAs (or DOE) would implement changes in containers and transportation infrastructure to improve the efficiency and cost-effectiveness of shipments. Figures 19-4 and 19-5 compare the current capabilities (CCP) and the maximum rail (MXR) scenarios in year 20 of the transportation program postulated in this analysis. Under the CCP scenario, rail shipments would be made from 37 sites and truck shipments from 27 sites; under the MXR scenario, 62 of 64 sites would be rail-capable. Modes are indicated as T1 and T2 for legal weight one- or two-assembly containers, or R75 and R125 for the small and large rail containers.

Origin	CCP Scenario Mode	CCP Scenario Casks	MXR Scenario Mode	MXR Scenario Casks
AL: Browns Ferry	T2	112	R125	6
AL: Farley	R125	6	R125	6
AR: Arkansas Nuc.	R75	11	R125	7
AZ: Palo Verde	R125	10	R125	10
CA: Diablo Canyon	T1	213	R125	11
CA: San Onofre	R125	5	R125	5
CT: Haddam Neck	T1	41	R75	4
FL: Crystal River	T1	66	R75	6
FL: St. Lucie	T1	139	R125	8
FL: Turkey Point	T1	88	R125	5
GA: Hatch	R125	10	R125	10
GA: Vogtle	R75	14	R75	14
IA: Duane Arnold	R75	6	R125	3
IL: Braidwood	R75	15	R125	9
IL: Byron	R75	20	R125	12
IL: Dresden	T2	439	R75	43
IL: La Salle	R75	19	R125	10
IL: Quad Cities	R75	15	R75	15
IL: Zion	R75	6	R125	4
KS: Wolf Creek	R125	4	R125	4
LA: River Bend	R125	5	R125	5
LA: Waterford	R125	5	R125	5
MA: Pilgrim	T2	74	R75	8
MD: Calvert Cliffs	T1	81	R125	4
ME: Maine Yankee	R125	3	R125	3
MI: Cook	T1	148	R125	8
MI: Fermi	T2	97	R125	5
MI: Palisades	T1	56	R125	3
MN: Monticello	T2	68	R75	7
MN: Prairie Island	R125	3	R125	3
MS: Grand Gulf	T2	140	R125	7
NC: Brunswick	R125	15	R125	15
NC: Harris	R75	4	R125	3
NC: McGuire	R75	20	R125	7
NE: Ft. Calhoun	T1	43	R75	4
NH: Seabrook	R125	4	R125	4
NJ: Hope Creek	T2	15	R125	7
NJ: Oyster Creek	T2	89	R125	5
NJ: Salem	T1	137	R125	8
NY: FitzPatrick	T2	100	R125	5
NY: Ginna	T1	38	T4	10
NY: Indian Point	T1	139	T4	18
OH: Davis-Besse	R125	3	R125	3
OH: Perry	R125	7	R125	7
PA: Beaver Valley	R75	11	R125	7
PA: Peach Bottom	T2	119	R125	6
PA: Susquehanna	R125	13	R125	13
PA: Three Mile Isld	R75	6	R125	4
SC: Catawba	R125	9	R125	9
SC: Oconee	T1	223	R125	12
SC: Robinson	R75	4	R75	4
SC: Savannah River	R	18	R	18
SC: Summer	R125	4	R125	4
TN: Sequoyah	R75	7	R125	5
TN: Watts Bar	R125	6	R125	6
TX: Comanche Peak	R125	13	R125	13
TX: South Texas	R125	7	R125	7
VA: North Anna	R75	6	R125	3
VA: Surry	T1	107	R125	6
VT: Vermont Yankee	T2	64	R75	7
WA: Hanford	R	143	R	143
WA: WNP	R125	4	R125	4
WI: Kewaunee	T1	37	R125	2
WI: Point Beach	T1	52	R125	4
TOTALS				
Truck		2,925		28
Rail		461		595

Figure 19-4. Year 20 Cask Shipments by Route and Origin
Current Capabilities Transportation Choices/Default Routing

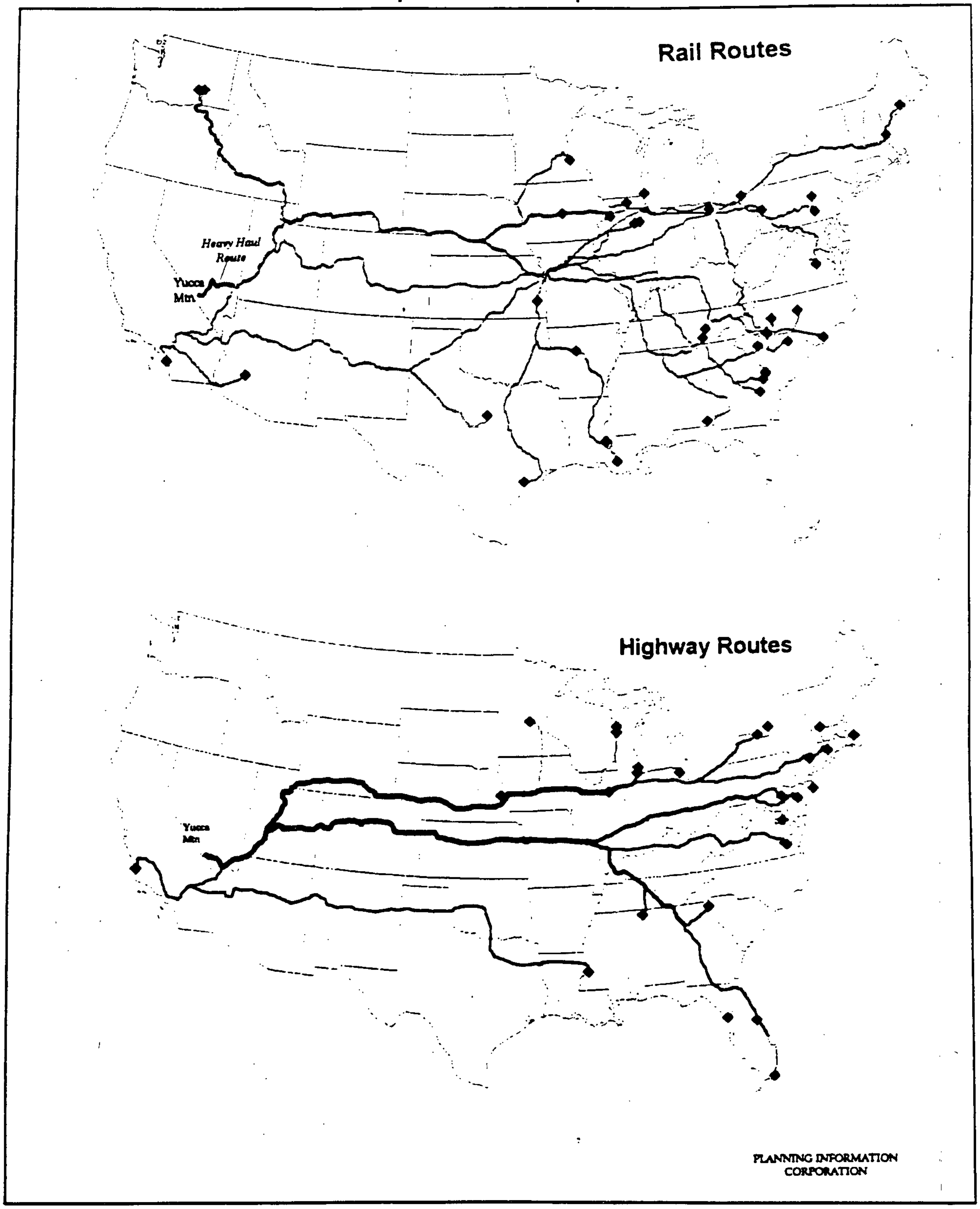
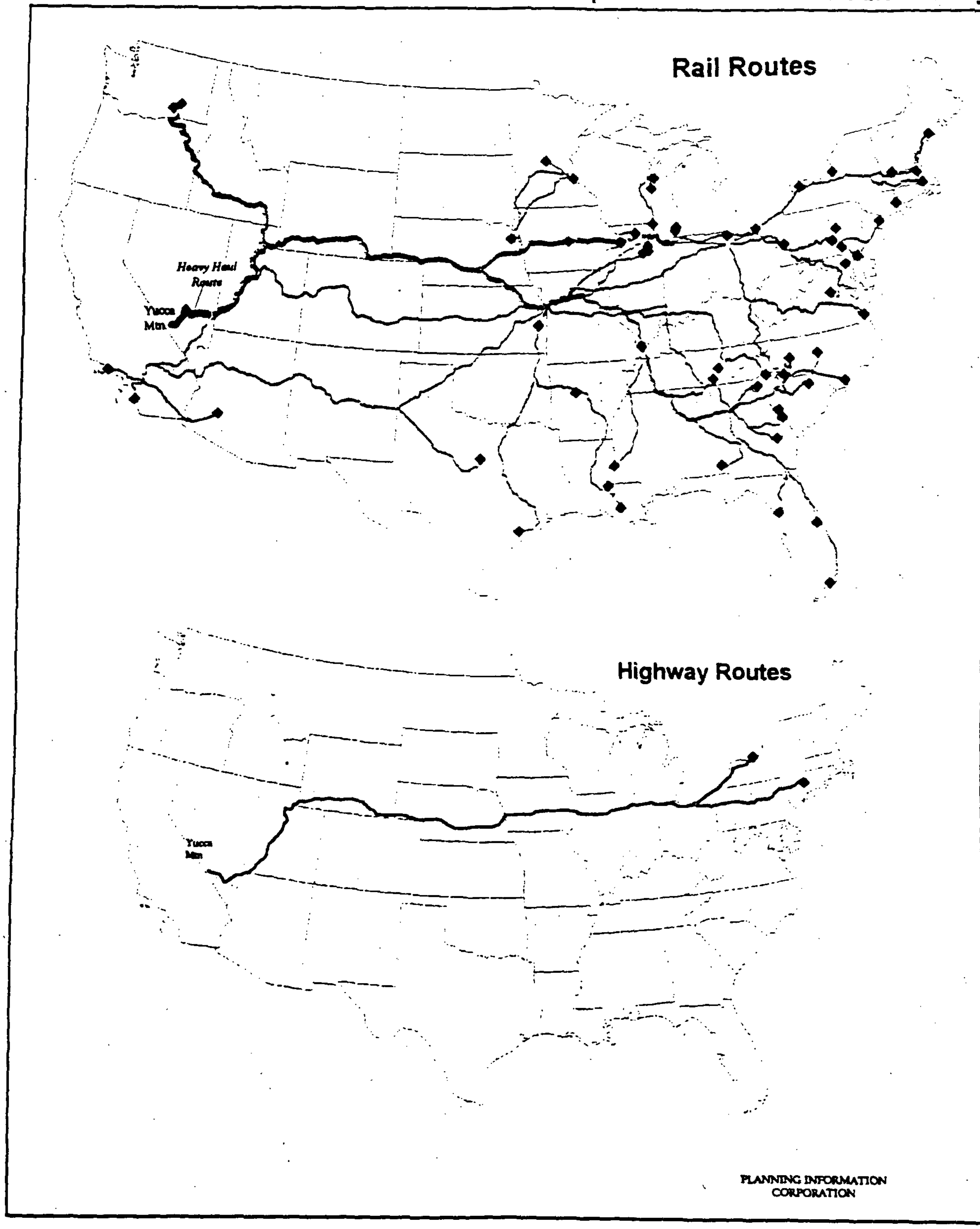


Figure 19-5. Year 20 Cask Shipments by Route and Origin Maximum Rail Transportation Choices/Default Routing



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20. TRANSPORTATION OPERATIONS REQUIREMENTS

Planning and managing a national shipment campaign requires reliable information on total metric tons shipped, total cask shipments, affected rail and highway route mileage, and total cask shipment miles. These variables yield useful indexes for comparing scenarios for the national shipment campaign: e.g., cask shipments per MTU shipped, cask shipments per affected route mile. Presented on an overall basis in this section, these measures may in other contexts be reviewed on a year-by-year or sub-region basis.

MTU Shipped

Given the inventory assumptions discussed in Section 2 above, about 86,600 MTU of SNF would be shipped to a centralized storage facility in Nevada. Given the acceptance rate assumptions discussed in Section 3, about 4,440 MTU would be shipped in the first three acceptance years. Given current capabilities transportation choices discussed in Section 11, about 36 percent of total MTU would be shipped via public highways, about 66 percent in the first three acceptance years. (This assumes, of course, that the centralized storage facility would be capable of receiving legal-weight truck shipments and reloading its bare fuel into storage canisters and casks.) Given the MPC base case scenario of transportation choices, about 11 percent of total MTU would be shipped by public highways, about 27 percent in the first three acceptance years. (This assumes the implementation of policies required to persuade utilities and/or regional servicing agents to upgrade loading facilities and near-site infrastructure.)

Cask Shipments

Given the cask options discussed in Section 6 and the "current capabilities" transportation choices discussed in section 11, about 92,000 cask shipments would be made over the 30-year shipment campaign, of which 86 percent would be on public highways by legal-weight truck. If the high-capacity GA-4/9 legal-weight truck were available and used throughout the shipment campaign, total cask shipments would be reduced to about 31,400, including about 71 percent by legal-weight truck.

During the first three acceptance years, about 8,200 casks shipments should be expected under the current capabilities scenario, almost all (96 percent) by legal-weight truck. Again, the high-capacity GA-4/9 cask, if available and used during the initial years, would reduce cask shipments substantially, from 8,200 to about 2,200. Even so, about 85 percent of the casks shipments would be by legal-weight truck on public highways. The MPC base case scenario of transportation choices, if implemented, would reduce total cask shipments from 92,000 to about 40,000 and the portion involving legal-weight truck shipments on public highways would be reduced from 86 percent to 65 percent. If, in addition, the high-capacity GA-4/9 cask were available and used, total casks shipments could be further reduced to 20,200, and the LWT portion of total cask shipment could be reduced to 31 percent.

Route Miles Affected

Given the transportation choices discussed in Section 11, and the default routing criteria discussed in Section 14, about 18,800 miles of railroad* and about 13,700 miles of public highways would receive shipments of SNF and/or HLW during the national shipment campaign. The MPC base case scenario of transportation choices increases the mileage of railroads impacted, from 18,800 to 21,200, and reduces the mileage of public highways impacted—from 13,700 to about 10,200. Total route mileage, however, is similar in the two cases—about 32,500 rail and highway route miles in the current capabilities scenario versus about 31,400 route miles in the MPC base case.

Route mileage impacted is the basic measure by which DOE proposes to allocate the variable amounts to be distributed to states for training local emergency responders and/or rail and highway inspectors.[25] In addition to a base amount provided to any affected state for planning and coordination, the variable amount would be allocated to response areas of an 80-mile radius, with no double counting of rail or highway routes within a response area (pg. 14). Wyoming, for example, with over 400 I-80 route miles and another 400 miles of UP railroad impacted under default routing, might receive variable funds for 2½ response areas. Nevada, where cask shipments could impact I-15, US-95, and the UP railroad, might receive variable funds for two response areas. The route mileage measure does not reflect the number of casks shipments along particular segments, or the amount of radioactive material in those shipments.

Cask Shipment Miles

Cask shipment miles, the product of cask shipments and distance from each origin site, is a measure which adjusts route mileage for the number of cask shipments expected along each segment. Given the cask options discussed in Section 6 and the current capabilities scenario of transportation choices discussed in Section 11, the national campaign would involve about 76 million cask shipment miles, 5 million in the first three acceptance years. Of these, 82 percent would be legal-weight truck shipments on public highways, 95 percent in the first three acceptance years.

The high-capacity GA-4/9 cask, if available and used, would substantially reduce total cask shipment miles, from 76 to 29 million, and from 5.1 million to 1.4 million over the first three acceptance years. The legal-weight truck portion of total cask shipment miles would be reduced (from 82 to 51 percent, from 95 to 82 percent in the first three acceptance years), but would still comprise a substantial majority of total cask shipment miles.

The MPC base case scenario of transportation choices, if implemented, would further reduce cask shipment miles, from 29 to 21 million and from 1.4 million to 1.0 million over the first three acceptance years. In the process, the legal-weight truck portion of total cask shipment miles would be reduced from 51 percent to about 27 percent, and from 82 percent to 66 percent in the first three acceptance years.

Identified by route segment, information on cask shipment miles would assist state and local officials to estimate route-specific accident and incident rates, allocate shipment monitoring and escorting efforts, estimate radiation exposure for corridor populations, etc.

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* Excluding the 162-mile heavy-haul route from Caliente to Yucca Mountain.

Cask Shipment Miles Per MTU Shipped

Cask shipment miles per MTU shipped is a measure of the amount of radioactive material in shipments expected along particular routes, or along all affected routes. It is one measure of the efficiency of the overall shipment campaign, or of its effects in particular corridor segments.

Given the current capabilities scenario of transportation choices, the average cask shipment mileage per MTU shipped is about 2,400 miles, about 4,300 over the first three acceptance years. On average, each MTU shipped by legal-weight truck requires 5,900 cask shipment miles, compared with about 430 cask shipment miles when shipped by rail.

The high-capacity GA-4/9 cask, if available and used, would substantially reduce cask shipment miles per MTU shipped, from 2,400 to about 820. The reduction reflects the reduction in cask shipment miles required to ship an MTU on public highways by legal-weight truck.

The MPC base case scenario of transportation choices, if implemented, would also effect a substantial reduction in cask shipment miles per MTU shipped. This reduction reflects the mix of rail and truck shipment in the MPC base case scenario. Cask shipment miles per MTU shipped by legal-weight truck is actually higher in the MPC base case than in the current capabilities scenario. Sites which are more difficult to upgrade for rail shipment are among those most distant from the Yucca Mountain destination.

Cask Shipments Per Route Mile Affected

How many cask shipments are expected over each route mile affected by the national shipment campaign? How many cask shipments are expected over particular route segments?

Given the current capabilities scenario of transportation choices (Section 11) and default routing criteria (Section 13) each affected rail route mile should expect about 1,500 rail cask shipments over the 30-year shipment campaign, and each affected highway route mile should expect about 13,400 LWT cask shipments.

The high-capacity GA-4/9 legal-weight truck cask, if available and used, would reduce cask shipments along each affected highway route mile from 13,400 to about 3,200.

The MPC base case scenario of transportation choices would reduce cask shipments along each affected highway route mile from about 13,400 to about 6,500, and shipments along each affected rail route mile (more rail route mileage is affected in the MPC base case) from 1,500 to about 1,460 rail casks.

Table 20-1. MTU Shipped, Cask Shipments, Route Miles Affected Cask Shipment Miles Life of Operations and Shipment Years 1 through 3 . . . Default Routing

	LIFE OF OPERATIONS (YR 1-31)......					SHIPMENT YEARS 1-3......				
	RAIL	HWY:T1/2	TOT:T1/2	HWY:T4/9	TOT:T4/9	RAIL	HWY:T1/2	TOT:T1/2	HWY:T4/9	TOT:T4/9
MTU SHIPPED:										
Current Capabilities	55593	31045	86638	31045	86638	1495	2944	4439	2944	4439
MPC Base Case	76844	9855	86699	9855	86699	3240	1200	4440	1200	4440
Maximum Rail	84704	1995	86699	1995	86699	4185	255	4440	255	4440
CASK SHIPMENTS:										
Current Capabilities	12636	79345	91981	31370	44006	327	7856	8183	1855	2182
MPC Base Case	13916	26093	40009	6322	20238	574	3352	3926	791	1365
Maximum Rail	16792	4722	21514	1150	17942	781	692	1473	181	962
ROUTE MILES AFFECTED:										
Current Capabilities	18805	13695	32500	13695	32500	18805	13695	32500	13695	32500
MPC Base Case	21210	10224	31434	10224	31434	21210	10224	31434	10224	31434
Maximum Rail	23507	4178	27685	4178	27685	23507	4178	27685	4178	27685
CASK SHIPMENT MILES:MIL										
Current Capabilities	14.0	62.3	76.3	14.7	28.7	0.8	18.2	19.1	4.3	5.1
MPC Base Case	15.3	24.1	39.4	5.7	21.0	1.4	8.2	9.6	1.9	3.3
Maximum Rail	16.8	4.0	20.8	1.0	17.8	1.9	1.7	3.6	0.4	2.4
CASK SHIP MI PER MTU:										
Current Capabilities	425	5892	2384	1391	823	2491	2322	2328	2322	2347
MPC Base Case	345	6749	1073	1593	539	2442	2458	2455	2458	2451
Maximum Rail	362	5790	487	1472	439	2471	2476	2473	2416	2461
CASK SHIP PER RT-MILE:										
Current Capabilities	1496	13356	6493	3154	2194	43	1332	586	314	158
MPC Base Case	1463	6505	3103	1536	1487	75	438	513	103	178
Maximum Rail	1494	2764	1686	703	1375	103	91	194	23	126

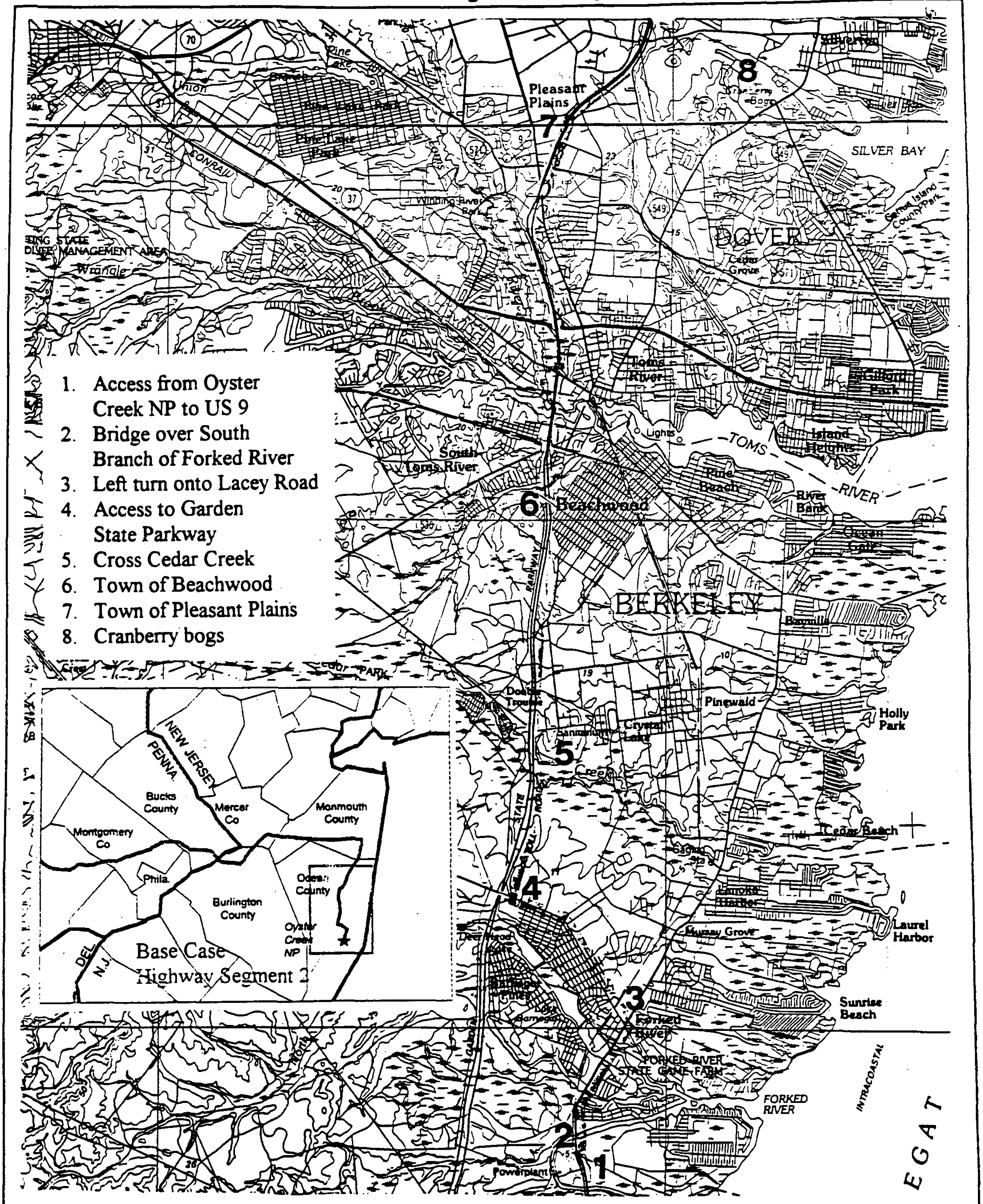
21. ROUTE FEATURES

The routing and cask shipment results presented in Sections 16 through 20 are in a sense only the first part of the information base required in planning and managing a national campaign for shipment of spent fuel and high-level waste. The second part is information regarding key features on or along the routes identified. The "key features" may include:

- Features of the route itself—e.g., bridges, intersections, grades, road geometry.
- Route conditions—e.g., pavement and bridge conditions, average daily and peak traffic flows, traffic service levels, accident rates.
- Route segments particularly affected by seasonal traffic, special event traffic, scheduled construction projects, or seasonal weather conditions.
- Facilities along routes which may require consideration in transportation options—e.g., schools, hospitals, sports stadiums, weighing stations, rest areas.
- Administrative boundaries—e.g., state, county, and city boundaries, state patrol and highway maintenance zones.
- Socioeconomic conditions—e.g., resident population, per capita income, workplace employment.
- Route-segment specific transportation management policies—e.g., state-designated routes, rush hour avoidance zones, designated rest or staging areas, safe havens.

Much of the relevant route-specific information must be assembled from various state and local sources. Other elements may be generated in process, as shippers coordinate with federal, state and local agencies in planning and managing a national shipment campaign. A geographically-referenced information base could help organize information on a complex and evolving array of topics and alternatives in origin and corridor communities, as well as provide a record of segment-specific policies and agreements among relevant stakeholders. The following figure[26] suggests how geographically-referenced information regarding route features might be developed, maintained and shared (in hard-copy or electronic form) among stakeholders in a national shipment campaign.

Figure 21-1. Oyster Creek Highway Route Features



APPENDIX A: TRANSPORTATION CHOICE SCENARIOS: DOE ASSUMPTIONS

While DOE has not estimated annual shipments by route segment, several DOE studies consider transportation choices on a site-by-site basis: a 1996 "preliminary transportation strategy study for a potential Nevada repository",[21] and a 1993 evaluation of the use of MPCs in DOE's high-level waste management system.[22] This appendix reviews the transportation choice assumptions in the two DOE studies, comparing them with those in the scenarios developed for this report.

Transportation Strategy Study 2

This study,[21] prepared as a basis for evaluating transportation options to a potential repository in Nevada, includes in Table F3 an estimate of the number of casks and MTU shipped from each commercial site and the four defense sites over the life of the program. The estimates are not annualized or keyed to proposed acceptance schedules or prioritization policies. Also, while the number of cask shipments is presented, the type of casks shipped is not.

To provide a basis for comparison, we have estimated the types of casks implied by Table F3 of DOE's Transportation Strategy Study 2 (see Table A-2): Data on the number of assemblies and MTU at each reactor was assembled (Ref #13, Table B6), aggregated for shipment sites, and used to calculate the average MTU per assembly at each site. The number of assemblies implied by the MTU in Table F3 was estimated by dividing MTU by the average MTU per assembly. The implied assemblies per cask was estimated by dividing assemblies by the number of casks identified in Table F3. The type of casks implied by Table F3 was identified by comparing estimated assemblies per cask with the capacity (in PWR or BWR assemblies) of small and large MPCs.

DOE's Transportation Strategy Study 2 implies that 11 sites which ship by truck in Nevada's MPC Base Case would instead ship by rail: Sites in columns 1 and 2 below would ship by small MPC, while those in column 3 would ship by large MPC.

Big Rock	LaCrosse	Palisades
Crystal River	Pilgrim	Peachbottom
Fort Calhoun	Vermont Yankee	St. Lucie
Humboldt Bay	Yankee Rowe	

Also, DOE's Transportation Strategy 2 implies that Three Mile Island would ship by large MPC, rather than by small MPC, as assumed in Nevada's MPC base case.

The transportation choices implied by DOE's study are, with the exception of a single site (Haddam Neck, assumed to ship by truck in the DOE study), identical to the "maximum rail scenario" discussed in Section 11 above, and could be implemented only through a set of incentives such as those discussed in the maximum rail scenario. Compared to Nevada's MPC base case, the transportation choices implied by DOE's study would significantly reduce highway impacts and total cask shipments, in the process increasing reliance on rail shipment. However, the necessary investments to improve cask loading capabilities and near-site infrastructure could be greater than those required under the MPC base case scenario of transportation choices, and substantially greater than under the current capabilities scenario.

Evaluation of Using MPCs

This study,[22] prepared as part of DOE's MPC initiative, includes in Appendix D a set of shipment projections "based on the assumption that individual utilities will request the largest cask they can effectively handle" (page D-1). The study did not include shipments of HLW or spent fuel from defense sites. Nor did it explain the basis for its judgement that 83 storage locations could effectively handle a large MPC, while 19 could effectively handle a small MPC, and only 14 require canistered truck shipments. Perhaps it refers to locations that, with incentives, could be upgraded to effectively handle the cask types specified. The study did consider storage locations, reaching different judgements for storage locations at the same site (e.g., Millstone 1 versus Millstone 2 and 3, San Onofre 1 versus San Onofre 2 and 3, St. Lucie 1 versus St. Lucie 2).

The MPC evaluation assumes ten storage locations would ship by truck (or require special handling: heavy-haul, cask-to-cask transfer, barge) which the transportation strategy study assumes will be shipped by rail:

Big Rock	Humboldt Bay	Callaway
Dresden 1	LaCrosse	Oconee
Fort Calhoun	Yankee Rowe	Point Beach
		San Onofre 1

The transportation strategy study assumes that the locations in columns 1 and 2 above would ship by small MPC, while those in column 3 would ship by large MPC.

The 1993 MPC evaluation and the 1996 transportation strategy study reach differing rail cask conclusions at thirteen sites:

Arkansas Nuclear	Rancho Seco	Brunswick
Duane Arnold	Salem	Dresden 2 and 3
Oyster Creek	Three Mile Island 1	Quad Cities
Palisades	Turkey Point	Robinson
		Vogtle

The transportation strategy study assumes that the locations in columns 1 and 2 would ship by large rail; the MPC evaluation assumes these locations would ship by small rail. The transportation strategy study assumes that the locations in column 3 would ship by small rail; the MPC evaluation assumes these locations would ship by large rail.

Table A-1. Utility Transportation Choice Scenarios: by Storage Location

	FUEL STRG LOCATION:	TRANSP CHOICE: TS2	TRANSP CHOICE: APD
1	ARKANSAS NUCLEAR 1	R125	R75
2	ARKANSAS NUCLEAR 2	R125	R75
3	ARKANSAS NUCLEAR DRY STRG	R125	R75
4	BEAVER VALLEY 1	R125	R125
5	BEAVER VALLEY 2	R125	R125
6	BELLEFONTE 1	R125	R125
7	BELLEFONTE 2	R125	R125
8	BIG ROCK 1	R75	LWT
9	BRAIDWOOD 1	R125	R125
10	BROWNS FERRY 1-2	R125	R125
11	BROWNS FERRY 3	R125	R125
12	BRUNSWICK 1	R75	R125
13	BRUNSWICK 1 PWR POOL	R75	R125
14	BRUNSWICK 2	R75	R125
15	BRUNSWICK 2 PWR POOL	R75	R125
16	BYRON 1	R125	R125
17	CALLAWAY 1	R125	LWT
18	CALVERT CLIFFS 1-2	R125	R125
19	CALVERT DRY STORAGE	R125	R125
20	CATAWBA 1	R125	R125
21	CATAWBA 2	R125	R125
22	CLINTON 1	R125	R125
23	COMANCHE PEAK 1	R125	R125
24	COOK 1	R125	R125
25	COOPER STATION	R75	R75
26	CRYSTAL RIVER 3	R75	R75
27	DAVIS-BESSE 1	R125	R125
28	DAVIS-BESSE DRY STRG	R125	R125
29	DIABLO CANYON 1	R125	R125
30	DIABLO CANYON 2	R125	R125
31	DRESDEN 1	R75	LWT
32	DRESDEN 2	R75	R125
33	DRESDEN 3	R75	R125
34	DUANE ARNOLD	R125	R75
35	ENRICO FERMI 2	R125	R125
36	FARLEY 1	R125	R125
37	FARLEY 2	R125	R125
38	FITZPATRICK	R125	R125
39	FORT CALHOUN	R75	LWT
40	FORT ST VRAIN	LWT	LWT
41	FORT ST VRAIN DRY STRG	LWT	LWT
42	GINNA	LWT	LWT
43	GRAND GULF 1	R125	R125
44	HADDAM NECK	LWT	LWT
45	HARRIS 1	R125	R125
46	HARRIS 1 BWR POOL	R125	R125
47	HATCH 1-2	R125	R125
48	HOPE CREEK	R125	R125
49	HUMBOLDT BAY	R75	LWT
50	INDIAN POINT 1	LWT	LWT
51	INDIAN POINT 2	LWT	LWT
52	INDIAN POINT 3	LWT	LWT
53	KEWAUNEE	R125	R125
54	LACROSSE	R75	T
55	LASALLE 1-2	R125	R125
56	LIMERICK 1-2	R125	R125
57	MAINE YANKEE	R125	R125
58	MCGUIRE 1	R125	R125
59	MCGUIRE 2	R125	R125
60	MILLSTONE 1	R75	R75
61	MILLSTONE 2	R75	R75
62	MILLSTONE 3	R75	R125
63	MONTICELLO	R75	R75
64	NINE MILE POINT 1	R125	R125
65	NINE MILE POINT 2	R125	R125
66	NORTH ANNA 1&2	R125	R125
67	NORTH ANNA DRY STRG	R125	R125
68	OCONEE 1&2	R125	LWT
69	OCONEE 3	R125	LWT
70	OCONEE DRY STORAGE	R125	LWT
71	OYSTER CREEK 1	R125	R75
72	OYSTER CREEK DRY STRG	R125	R75
73	PALISADES	R125	R75
74	PALISADES DRY STORAGE	R125	R75
75	PALO VERDE 1	R125	R125
76	PALO VERDE 2	R125	R125
77	PALO VERDE 3	R125	LWT
78	PEACHBOTTOM 2	R125	LWT
79	PEACHBOTTOM 3	R125	LWT
80	PERRY 1	R125	R125
81	PILGRIM 1	R75	R75
82	POINT BEACH 1&2	R125	R125
83	POINT BEACH DRY STRG	R125	R125
84	PRAIRIE ISLAND 1&2	R125	R125
85	PRAIRIE ISLAND DRY STRG	R125	R125
86	QUAD CITIES 1	R75	R125
87	RANCHO SECO 1	R125	R75
88	RANCHO SECO DRY STRG	R125	R75
89	RIVER BEND 1	R125	R125
90	ROBINSON 2	R75	R125
91	ROBINSON DRY STORAGE	R75	R125
92	SALEM 1	R125	R75
93	SALEM 2	R125	R75
94	SAN ONOFRE 1	R125	LWT
95	SAN ONOFRE 2	R125	R125
96	SAN ONOFRE 3	R125	R125
97	SEABROOK 1	R125	R125
98	SEQUOYAH 1	R125	R125
99	SHOREHAM	NA	NA
100	SOUTH TEXAS 1	R125	R125
101	SOUTH TEXAS 2	R125	R125
102	ST LUCIE 1	R125	R125
103	ST LUCIE 2	R125	R125
104	SUMMER 1	R125	R125
105	SURRY 1&2	R125	R125
106	SURRY DRY STORAGE	R125	R125
107	SUSQUEHANNA 1-2	R125	R125
108	SUSQUEHANNA DRY STRG	R125	R125
109	THREE MILE ISLAND 1	R125	R75
110	TROJAN	R125	R125
111	TURKEY POINT 3	R125	R75
112	TURKEY POINT 4	R125	R75
113	VERMONT YANKEE 1	R75	R75
114	VOGTLE 1-2	R75	R125
115	WASH NUCLEAR 2	R125	R125
116	WATTS BAR 1&2	R125	R125
117	WATERFORD 3	R125	R125
118	WOLF CREEK 1	R125	R125
119	YANKEE-ROWE 1	R75	LWT
120	ZION 1&2	R125	R125
121	HANFORD SNF STRG	LWT	LWT
122	HANFORD SNF STRG	LWT	LWT
123	INEL SNF STRG	LWT	LWT
124	INEL SNF STRG	LWT	LWT
125	INEL SNF STRG	LWT	LWT
126	SAVANNAH RV SNF STRG	LWT	LWT
127	SAVANNAH RV SNF STRG	LWT	LWT
128	WEST VALLEY SNF STRG	R125	LWT
129	WEST VALLEY SNF STRG	R125	LWT
130	MORRIS	R125	R125
131	MORRIS	R125	R125
132	GENERAL ATOMICS	LWT	LWT

Shipment Cask Options:
R125: Large MPC for up to 21 PWR or 40 BWR
R75: Small MPC for up to 12 PWR or 24 BWR
LWT: Legal-weight truck casks.... GA-4/9 if a NLI-1/2 or NAC LWT otherwise

Transp Choice: TR2: NV Transp Strategy, Study 2 (DOE: Feb'96, Tbl F-3), PIC
APD: MPC Prelim Evaluation (DOE: Mar 1993, Appendix D)

Table A-2. Cask Types Implied by DOE's Transportation Strategy Study 2

		DOE TR2:TBL F3		PIC EVALUATION:			
SITE#	NUCLEAR REACTOR SITES:	CASKS	MTU	REAC TYPE	MTU/A	A/CASK	EST C-TYPE
1	ARKANSAS NUCLEAR 1,2	128	1151	PWR	0.44	20	R125
2	BEAVER VALLEY 1,2	106	1015	PWR	0.46	21	R125
3	BELLEFONTE 1,2	0	0	PWR	NA	NA	???
4	BIG ROCK	40	63	BWR	0.13	12	R75
5	BRAIDWOOD 1,2	119	1049	PWR	0.42	21	R125
6	BROWNS FERRY 1,2,3	210	1537	BWR	0.19	39	R125
7	BRUNSWICK 1,2	207	915	BWR	0.18	24	R75
8	BYRON 1,2	130	1147	PWR	0.42	21	R125
9	CALLAWAY 1	75	640	PWR	0.44	19	R125
10	CALVERT CLIFFS 1,2	145	1143	PWR	0.38	21	R125
11	CATAWBA 1,2	128	1193	PWR	0.43	22	R125
12	CLINTON 1	65	453	BWR	0.18	38	R125
13	COMANCHE PEAK 1,2	105	918	PWR	0.45	19	R125
14	COOK 1,2	146	1350	PWR	0.44	21	R125
15	COOPER STATION	106	458	BWR	0.19	23	R75
16	CRYSTAL RIVER 3	89	491	PWR	0.46	12	R75
17	DAVIS-BESSE 1	58	509	PWR	0.47	19	R125
18	DIABLO CANYON 1,2	133	1191	PWR	0.45	20	R125
19	DRESDEN 1,2,3	355	1424	BWR	0.17	23	R75
20	DUANE ARNOLD	64	457	BWR	0.18	39	R125
21	ENRICO FERMI 2	77	501	BWR	0.18	36	R125
22	FARLEY 1,2	123	1140	PWR	0.46	20	R125
23	FITZPATRICK	73	519	BWR	0.18	39	R125
34	FORT CALHOUN	89	381	PWR	0.36	12	R75
25	FORT ST VRAIN	???	???	HTG	0.01	NA	LWT
26	GINNA	???	???	PWR	0.38	NA	LWT
27	GRAND GULF 1	121	852	BWR	0.18	39	R125
28	HADDAM NECK	???	???	PWR	0.41	NA	LWT
29	HARRIS 1	69	598	PWR	0.45	19	R125
29	HARRIS 1 BWR POOL	???	???	BWR	0.19	NA	R125
30	HATCH 1,2	184	1332	BWR	0.18	39	R125
31	HOPE CREEK	101	717	BWR	0.19	38	R125
32	HUMBOLDT BAY	17	29	BWR	0.07	23	R75
33	INDIAN POINT 1,2,3	???	???	PWR	0.43	NA	LWT
34	KEWAUNEE	59	466	PWR	0.39	21	R125
35	LACROSSE	14	38	BWR	0.11	24	R75
36	LASALLE 1,2	176	1262	BWR	0.18	39	R125
37	LIMERICK 1,2	165	1129	BWR	0.18	37	R125
38	MAINE YANKEE	91	717	PWR	0.38	21	R125
39	MCGUIRE 1,2	151	1419	PWR	0.44	22	R125
40	MILLSTONE 1,2,3	347	1734	BWR	0.26	19	R75
41	MONTICELLO	95	394	BWR	0.18	23	R75
42	NINE MILE POINT 1,2	148	1030	BWR	0.19	38	R125
43	NORTH ANNA 1,2	131	1149	PWR	0.46	19	R125
44	OCONEE 1,2,3	204	1897	PWR	0.46	20	R125
45	OYSTER CREEK 1	92	651	BWR	0.18	39	R125
46	PALISADES	69	575	PWR	0.40	21	R125
47	PALO VERDE 1,2,3	204	1687	PWR	0.41	20	R125
48	PEACHBOTTOM 2,3	225	1602	BWR	0.18	38	R125
49	PERRY 1	86	605	BWR	0.18	38	R125
50	PILGRIM 1	117	506	BWR	0.19	23	R75
51	POINT BEACH 1,2	107	837	PWR	0.39	20	R125
52	PRAIRIE ISLAND 1,2	106	807	PWR	0.38	20	R125
53	QUAD CITIES 1,2	314	1347	BWR	0.18	23	R75
54	RANCHO SECO 1	24	228	PWR	0.46	21	R125
55	RIVER BEND 1	69	488	BWR	0.18	38	R125
56	ROBINSON 2	70	345	PWR	0.44	11	R75
57	SALEM 1,2	123	1136	PWR	0.46	20	R125
58	SAN ONOFRE 1,2,3	175	1469	PWR	0.40	21	R125
59	SEABROOK 1	47	439	PWR	0.46	20	R125
60	SEQUOYAH 1,2	103	979	PWR	0.46	21	R125
61	SHOREHAM	0	0	BWR	NA	NA	NA
62	SOUTH TEXAS 1,2	76	808	PWR	0.54	20	R125
63	ST. LUCIE 1,2	147	1151	PWR	0.38	21	R125
64	SUMMER 1	59	525	PWR	0.45	20	R125
65	SURRY 1,2	120	1085	PWR	0.46	20	R125
66	SUSQUEHANNA 1,2	211	1470	BWR	0.18	39	R125
67	THREE MILE ISLAND 1	56	523	PWR	0.46	20	R125
68	TROJAN	38	359	PWR	0.46	21	R125
69	TURKEY POINT 3,4	107	1011	PWR	0.46	21	R125
70	VERMONT YANKEE 1	138	602	BWR	0.18	24	R75
71	VOGTLE 1,2	218	1024	PWR	0.46	10	R75
72	WASHINGTON NUCLEAR 2,3	81	555	BWR	0.18	38	R125
73	WATERFORD 3	75	597	PWR	0.41	19	R125
74	WATTS BAR 1,2	32	300	PWR	0.46	20	R125
75	WOLF CREEK 1	63	575	PWR	0.46	20	R125
76	YANKEE-ROWE 1	45	127	PWR	0.24	12	R75
77	ZION 1,2	144	1375	PWR	0.46	21	R125
	Sub-Total	8385	60195		0.28	25	

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