THE EFFECTS OF REGIONAL MANAGEMENT ON TRANSPORTATION REQUIREMENTS FOR LOW-LEVEL WASTE*

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INTRODUCTION

Through the Low-Level Radioactive Waste Policy Act of 1980 (PL96-573), the 96th Congress of the United States instructed the Secretary of the Department of Energy (DOE) to prepare a report[1] on the current U.S. low-level waste (LLW) management system and on the conditions and requirements for management on a regional basis. Section 4.(b) (1) (C) of PL96-573 specified that the DOE report "evaluate(s) the transportation requirements on a regional basis and in comparison with performance of present transportation practices for the shipment of low-level wastes, including an inventory of types and quantities of low-level wastes, and evaluation of shipment requirements for each type of waste and an evaluation of the ability of generators, shippers, and carriers to meet such requirements."

The Transportation Technology Center (TTC) at Sandia National Laboratories (SNL) was asked by DOE to provide the specified analysis of the transportation requirements and the ability to meet those requirements. The TTC performed the requested analysis and assisted in the preparation of the DOE final response to Congress, which was published in July 1981[1].

The report to Congress presented the results of an analysis[2] of two LLW management options: present practice (three national disposal facilities) and regional management. These results show that national LLW transportation requirements could be reduced by a factor of two if management according to DOE-postulated regions is implemented.

To compare possible regional LLW management in the future to current practice within the information available, the regional transportation system could only be described using approximations and assumptions. In particular, it was assumed that (1) the regional divisions were those postulated prior to most of the interstate compact negotiations that have occurred to date and (2) each state in a region was equally likely to host a regional disposal site, without regard to the location of LLW sources in the regions.

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The latter assumption was made to obtain an estimate of the upper regional transportation requirements.

To supplement the results reported in References 1 and 2, this paper presents additional analyses of regional LLW transportation requirements for the DOE-postulated regions and for the management regions being formed in current negotiations among the states.

LLW MANAGEMENT CASES CONSIDERED

Public Law 96-573 (the Act) places the responsibility for LLW management on the states and encourages the formation of regional compacts among cooperating states to fulfill this responsibility. As a result, there is currently much activity among states to enter into agreements to share LLW management responsibilities. At least three regional compacts are being actively pursued: Northwest Compact, Southern States Compact, and Rocky Mountain Compact.[3] Because the Act authorizes regions that have established compacts to exclude out-of-region waste after January 1, 1986, activity will continue to increase as this deadline approaches.

Four LLW management cases are considered in this paper. The first case, shown in Fig. 1, examined the status-quo: (a) states were assumed to continue shipping low-level waste according to patterns established in 1979 and (b) existing disposal sites were used. The second case assigned states into regions suggested by the DOE for use in preparing a response to the Act. The regions are shown in Fig. 2. In examining the second case, regional disposal-site locations were not optimized for transportation, but rather, disposal sites were assumed to be equally likely to be established in any state within a region. The third case considered the same regions as shown in Fig. 2. In regions

Fig. 1. Current Practice (Case 1): Three Disposal Sites for LLW

Fig. 2. DOE-Suggested Regions (Cases 2 and 3)

Fig. 3. Currently-Negotiating Regions (Case 4)

which contain them, existing sites were assumed to continue as the regional disposal sites. Disposal sites in other regions were located so as to reduce transportation distances. The fourth case considered is shown in Fig. 3. This case reflects recent trends in regionalization as discussed in Reference 3. Some of the regions are similar to those proposed by the DOE; the northeast region is identical. However, some states such as Texas and California appear to be inclined to solve their disposal problems on their own without the affiliation of a regional compact with other states. The disposal sites were located, in the fourth case, so as to reduce transportation requirements: existing disposal sites were used unless an alternate location significantly reduced transportation requirements.

BASES OF ANALYSIS

Because of the variation of LLW characteristics, many assumptions had to be made regarding: shipment descriptions, volumes of waste shipped according to source type, shipment patterns to existing disposal sites, and cost factors.

Shipment Descriptions

Table I describes: each subcategory of waste in qualitative terms, the Department of Transportation (DOT) transport category of the packaging required for shipment, and the capacity of the packaging. Waste is generated by three different source types: reactor LLW, industrial LLW, and institutional LLW. Each produces LLW with different physical and radiological characteristics. Wastes from the first two sources are further subcategorized according to the radiological characteristics of the waste. This additional categorization is important because the radiological character determines the type of packaging that must be used to transport the LLW. Furthermore, the type of packaging determines the volume of LLW that can be accommodated in a shipment. All shipments were based on a volume limit rather than a weight limit because available waste descriptions in Reference 4 are in terms of volumes and not weights.

As the radiological hazard of the LLW increases, the strength of the packaging used to transport the waste increases. An LSA packaging could be a metal drum or wooden box that is strong and tight, while a Type A packaging, which could also be a drum or box, is required to survive regulatory test conditions [49CFR 173.393 (b)] that are similar to those encountered during normal transport (such conditions as a drop from a tailgate, standing out in a rain storm, or being in the sun for an extended period). A Type A packaging will provide radiation shielding as required to limit external radiation to statutory requirements (49CFR 173.393). Type B packagings are stronger packagings and are required to survive not only the normal test conditions but also to survive accident test conditions of transport [impact, puncture, and fire as specified in 49CFR173.398(c)].

TABLE I. TYPICAL LOW-LEVEL WASTE SHIPMENT CHARACTERISTICS AND TRANSPORT CATEGORIES

LLW Source and Shipment Type[1]	Waste Description	Typical DOT Transport Category	Typical Transport Package Type and Maximum Payload per Shipment (m^3)
Reactor LLW			
I	Low-activity dry compressible waste and contaminated equipment	LSA or Type A	Strong industrial or certified Type A package; $25m^3$ per shipment
II	Low-activity spent resins, filter sludges, and evaporator bottoms	Type A or B	Certified Type A or B package with adequate shielding; $9m^3$ per shipment
III	High-activity spent resins, filter sludges, and evaporator bottoms	Type B	Certified Type B package with adequate shielding; $6m^3$ per shipment
IV	High-activity irradiated components	Type B	Certified Type B package with adequate shielding; $4m^3$ per shipment
Industrial LLW			
I	Low-activity wastes	LSA or Type A	Strong industrial or certified Type A package; $25m^3$ per shipment
II	High-activity wastes	Type A or B	Certified Type A or B package with adequate shielding; $10m^3$ per shipment
Institutional LLW			
I	Low-activity wastes	LSA or Type A	Strong industrial or certified Type A package; $25m^3$ per shipment

[1] Shipment types are used in this analysis as defined here and should not be considered as transport groups.

A wide variety of packagings exist to transport LLW. The selection of a packaging for any given shipment is determined by the physical and radiological characteristics of the LLW. As a result, the volume of waste that can be transported in a given shipment is also dependent on the characteristics of the waste. The packaging volumes indicated in Table I do not apply to many specific shipments but are expected to be good estimates of average shipment volumes.

Volumes of Waste Shipped in 1979

The volumes of waste shipped in the U.S. in 1979 are shown in Table II according to the waste source and shipment type. These values are taken from Reference 4 and are based on information gathered for 1979 only. All LLW management cases consider the 1979 volumes so that a comparison can be made using a consistent basis. As Table II indicates, reactor waste volumes dominate, contributing over half of the national total volume.

TABLE II. VOLUMES OF LOW-LEVEL RADIOACTIVE WASTE SHIPPED TO COMMERCIAL DISPOSAL SITES IN 1979 (U.S. Total)[2]

Reactor LLW (m^3)	
Type I	21,140
Type II	14,140
Type III	1,570
Type IV	2,620
Total	39,470
Industrial LLW (m^3)	
Type I	15,630
Type II	3,910
Total	19,540
Institutional LLW (m^3)	
Type I	13,610
Total	13,610
Total LLW (m^3)	
TOTAL	72,620

Percentage of Shipments Made to Existing Sites

The average percentages of shipments from each state to existing disposal sites are also taken from Reference 4. As would be expected, shipments to the Barnwell disposal site in South Carolina originate primarily east of the Mississippi River. The site near Beatty, Nevada, receives very little LLW from east of the Mississippi and shares the LLW from the West with the site at Hanford, Washington. The Hanford site receives slightly more waste from the East than the Beatty site does. On a nationwide basis, the percentage by volume of waste received at Barnwell, Beatty, and Hanford are 79%, 8%, and 13%, respectively.

These percentages, as further reduced according to state-by-state values, are used only when evaluating Case 1.

Cost Factors

The cost factors for each shipment type are given in Table III. They are based on exclusive-use shipment of the LLW. Exclusive-use vehicles are dedicated to the LLW waste being hauled; no other cargo is hauled with the LLW. Though not universally used for LLW waste shipments, exclusive-use truck shipments are the most representative mode of shipment.

The costs estimated in the table are only representative since actual shipment costs are negotiated with the carrier and/or owner of the packaging. Trip duration estimates are required in order to estimate the cost of renting overpacks, generally specialized Type A and Type B packagings. These special packagings most probably are dead-leg hauls (a haul in which a packaging returns to the shipment origin empty) and so must be rented for a round trip. The duration of shipments is assumed to have a breakpoint at 800 km as are the mileage charges. Generally, these mileage charges are lower with increased shipment distances.

SOURCE AND DISPOSAL SITE LOCATIONS

An important part of the analysis of the transportation requirements for LLW is to approximate the locations of the sources and disposal sites in order to estimate shipping distances. The method for approximating source locations is consistent for all four management cases considered. However, the method for approximating disposal-site locations varied with each case.

Source locations had to be approximated for each of the three LLW source types that may be present in each state. The reactor location for each state was assumed to be at the geometric centroid of actual reactor locations within the state. The industrial and institutional locations for each state were assumed to be at the geometric centroids of population centers of over 100,000 people.

The disposal site locations varied according to each case. For Case 1, which is the status quo case, the disposal site locations used were the existing site locations: Barnwell, SC; Beatty, NV; and Hanford, WA. The distances from the sources to disposal sites were estimated with "crow-flight" measurements that were adjusted using a multiplier of 1.25 to obtain highway distances."[5]

TABLE III. NOMINAL LOW-LEVEL WASTE TRANSPORTATION COST FACTORS

LLW Source	Shipment Types	Trip Durations (days)				Mileage Charges ($ per one-way kilometer)		Overpack Rental ($ per day)
		Round Trip		One-Way Trip				
		<800 km	>800 km	<800 km	>800 km	<800 km	>800 km	
Reactor	I	NA	NA	2	4	1.25	1.10	NA
	II	4	10	NA	NA	1.85	1.70	200
	III	4	10	NA	NA	1.85	1.70	400
	IV	4	10	NA	NA	1.85	1.70	500
Industrial	I	NA	NA	2	4	1.25	1.10	NA
	II	4	10	NA	NA	1.85	1.70	300
Institutional	I	NA	NA	2	4	1.25	1.10	NA

In Case 2, no particular site was identified within a region, but rather, a disposal location was assigned in the least populated area of each individual state. Distances were estimated from the sources in each state to the disposal sites in each of all the states in the region. Then, an average distance of shipment was calculated for each source type in each state.

In Case 3, distances to existing disposal sites were estimated in regions that have them. For regions which do not currently have existing disposal sites, transportation distances were reduced over those in Case 2. These reduced distances were obtained by selecting a disposal site location nearer to the largest (by volume) LLW sources in the region than to the centroid of all the LLW generator locations.

Case 4 was also examined using this "volume-weighted centroid" method to estimate shipment distances, except in regions where disposal sites that exist are expected to continue operation: Hanford, Washington, and Barnwell, South Carolina. In some regions that were only single states, the volume-weighted centroid method was used if more than one of the three types of LLW sources were operating in the state. If there was only one source type in the state, a reasonably small distance to the disposal site was estimated based on population distribution. With the exception of the existing sites, the geographical locations of the disposal sites were not actually defined, and as a result, they are not shown in Figs. 1-3.

METHOD OF ANALYSIS

The method used to analyze the transportation requirements is detailed in the flow diagram shown in Fig. 4. Steps A, B, and C of the method have been discussed in the previous section. The result of these steps is the shipment distance from each source to a disposal site. Steps D and E use information similar to that presented in Table II except that information for each state is used. Then, the number of shipments for each shipment type by source type is calculated for each state in Steps F, G, and H. It is at this point that the cumulative distance traveled is obtained by combining Steps C and H in Step I. The total transportation costs are calculated in Step J. Steps A through J are then repeated for each source in each state. Steps K and L combine the individual state results by region and finally nationwide.

This sequence of steps has been completed for each of the four cases considered using the annual volumes indicated in Table II. The sequence of steps for each case was identical except in Steps B and H. As previously discussed, disposal site selection (performed in Step B) was different from case to case, and in Step H, more than one disposal site was used by the sources within a state in Case 1.

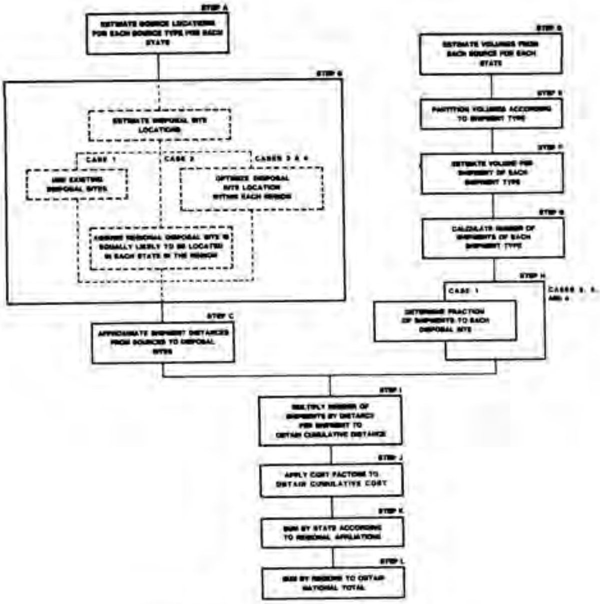

Fig. 4. Method of Analysis

SUMMARY OF RESULTS

The distances traveled and the costs for each LLW management case are given in Table IV. The comparison was made using the 1979 LLW volumes estimated in Reference 4 for each case regardless of the fact that Cases 2, 3, and 4 could probably not be viable until the late 1980's. The values for each generator type are given in the first three columns and are totaled in the final column. The values for distance are given in thousands of kilometers and the values for costs are presented in thousands of dollars.

Several observations can be made after reviewing the information in the table. Case 4, which involves regions defined according to current negotiations among states, requires roughly 25% of the expense and distance traveled that is required for Case 1, which is the status quo. Indeed, Cases 3 and 4 should have reduced costs and transport distances because their disposal sites were located to reduce transportation distance. Reactor LLW dominates

TABLE IV. DISTANCES TRAVELED AND COSTS FOR EACH REGIONALIZATION OPTION (Using 1979 LLW Volumes as a Basis)[a]

Case	Reactor LLW		Industrial LLW		Institutional LLW		Total LLW	
	Distance (10^3 km)	\$(10^3)	Distance (10^3 km)	\$(10^3)	Distance (10^3 km)	\$(10^3)	Distance (10^3 km)	\$(10^3)
1	4800	7800	1100	2300	980	1100	6900	11,000
2	2000	3500	700	920	370	470	3100	4900
3	1300	2400	360	580	240	280	1900	3200
4	1100	2000	280	440	170	210	1600	2600

[a]Reference 2

the cost and distance travel required in all of the cases. In addition, the ratio for distance traveled to cost of travel for reactor LLW is frequently higher than for the other sources. This observation results from the fact that many reactor LLW shipments require great amounts of shielding, and thus, require packagings that are more expensive to rent.

Two general observations can be made based on the results in Table IV. First, a reduction in national LLW transportation requirements by a factor ranging from 2 to 4 can be achieved by converting the present LLW management system to a regional system. Second, LLW transportation requirements are reduced as the sizes of the management regions are made smaller. These observations and the results in Table IV suggest that the largest reduction factor of 4 in total transportation distances and costs can be attained by the regional compacts currently under negotiation if transportation requirements are given appropriate consideration in addition to other concerns in disposal site selection.

CONCLUSIONS

The state compacts as now presently being negotiated will clearly reduce distances traveled to transport LLW and thus will reduce national transportation costs. Furthermore, it is important to note that risk to the public from LLW transport, which as a rule decreases with decreasing distance of travel, also will be reduced markedly.

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