DECISION ANALYSIS USED IN THE PRELIMINARY SELECTION OF A LOW-LEVEL RADIOACTIVE WASTE DISPOSAL TECHNOLOGY FOR THE STATE OF TEXAS

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ABSTRACT

The Texas Low-Level Radioactive Waste Disposal Authority (the Authority) is in the process of developing a low-level radioactive waste disposal facility for waste generated in the State of Texas. In this process it found necessary and desirable to limit the extent of the preliminary investigations to a few disposal technologies which appeared to best suit the technical and sociopolitical needs of the State and its citizens. Thus, a methodology was used whereby the technical performance characteristics were considered together with the importance of each issue or factor used to judge the performance to find a relative ranking of eleven disposal technologies. This paper briefly presents the methodology and the results of the ranking and scoring process.

INTRODUCTION

The Texas Low-Level Radioactive Waste Disposal Authority (the Authority) is in the process of developing a low-level radioactive waste disposal facility for waste generated in the State of Texas. In this process it was found necessary and desirable to limit the extent of the preliminary investigations to a few disposal technologies which appeared to best suit the technical and sociopolitical needs of the State and its citizens. Thus, a multi-attribute utility estimation methodology was used whereby the technical performance characteristics were considered together with the importance of each issue or factor used to judge the performance to find a relative ranking of eleven disposal technologies. Initially eleven different disposal technologies were listed and described to all participants in the evaluation process. The eleven disposal technologies are listed in Table I.

METHODOLOGY

The decision analysis methodology used is similar to those used by others for questions of comparable technical complexity and sociopolitical difficulty(1,2). The methodology is a multi-attribute utility estimation. It recognizes that the importance of issues and factors used to judge the performance of a disposal technology are independent of the expected performance of each. The relative importance of issues and factors may be determined by those who will be affected by the facility. It also requires the involvement of those who are intimately familiar with the performance characteristics of the various disposal technologies, who are able to rate the technologies on a relative technical basis. The disposal technology selection process is shown in Fig. 1.

All issues are broad enough to consist of two or more specific factors. A factor is a specific consideration that more precisely identifies an issue. Each factor may be thought of as representing a particular concern of the public about low-level waste disposal.

Once the factors were defined, they were used by two independent groups as illustrated in Fig. 2. The first group, comprised of members of the non-technical public, assigned importance weights to the issues and to their component factors. The weights represent the relative importance the public attached to each. The sum of all factor importance weights for a given issue is 1.00.

TABLE I

LOW-LEVEL RADIOACTIVE WASTE DISPOSAL TECHNOLOGIES CONSIDERED IN THE DECISION ANALYSIS

Name	Abbreviation
Shallow land disposal	SLD
Improved shallow land disposal	ISLD
Above-ground vaults	AGV
Below-ground vaults	BGV
Above-ground modular concrete canisters	MCCD-A
Above/below-ground modular concrete canisters	MCCD-AB
Below-ground modular concrete canisters	MCCD-B
Earth-mounded concrete bunkers	EMCB
Mined cavities	MCD
Unlined augered holes	AHU
Lined augered holes	AHL

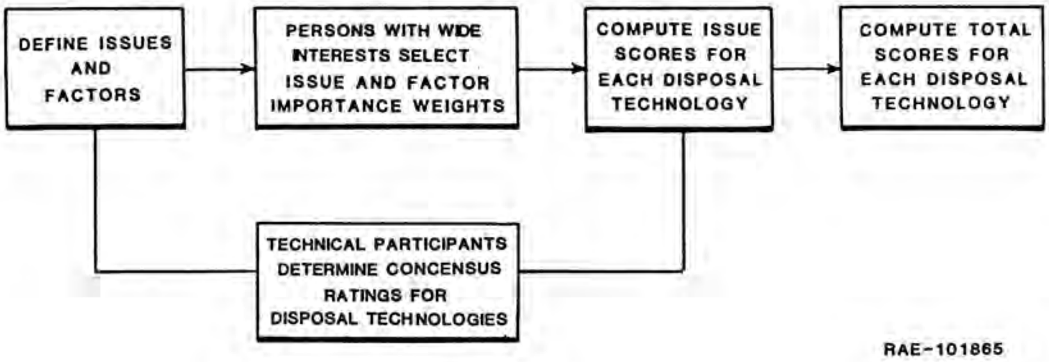

Fig. 1. Low-Level Radioactive Waste Disposal Technology Selection Process Utilized by the Authority.

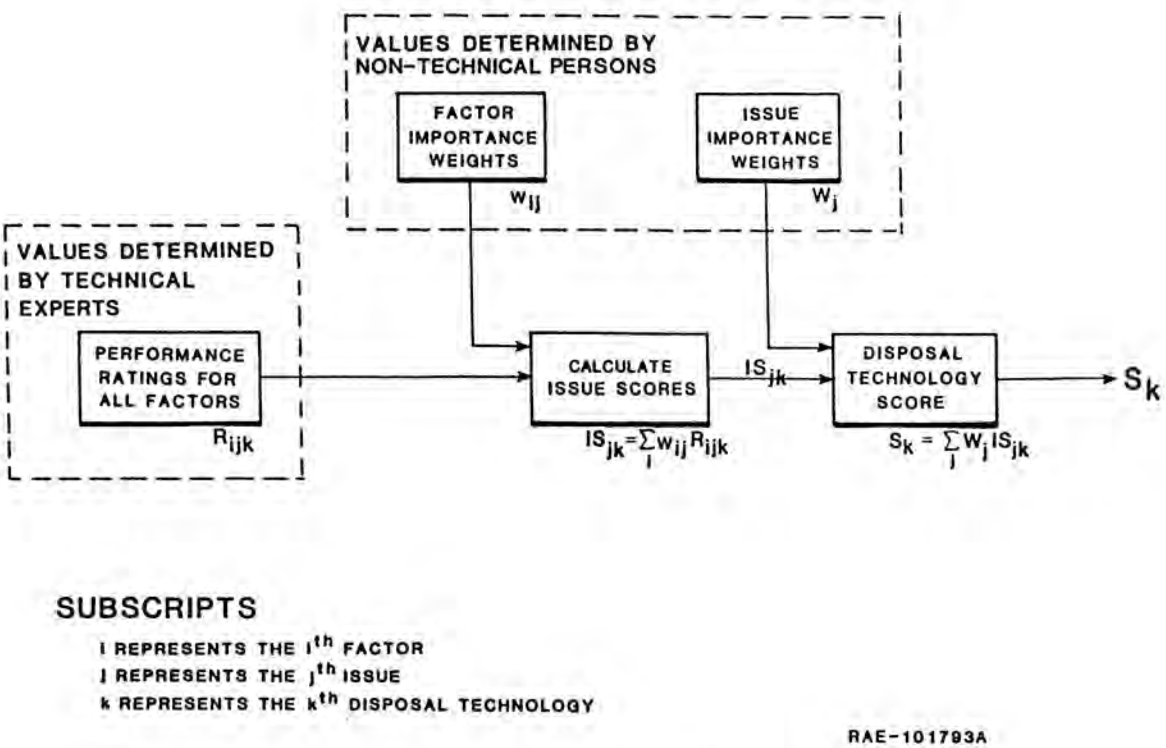

Fig. 2. Schematic Representation of Decision Methodology.

The second group, consisting of technical experts, rated the performance of each candidate disposal technology according to each factor. Each disposal technology was assigned a rating ranging from 1.0 (least attractive) to 5.0 (most attractive), depending on the technical experts' judgement of how well it satisfied the objectives stated by the factors. Factor performance ratings were normalized to minimize scoring biases among the participants.

Weighted sums or issue scores were calculated for each issue by taking the product of each factor importance weight and the respective performance rating and summing these over all factors for a particular issue. These values, in turn, were weighted by the issue importance factors, which were summed across all issues to yield a final score for each disposal technology. The procedure illustrated in Fig. 2 was followed for all eleven disposal technologies.

Following the initial analysis, a number of sensitivity analyses of issue importance weights to the disposal technology scores were conducted. In one case, all issue importance weights were assumed uniform and the scores determined. In a second case, the issue importance weights, as assigned by the public participants, were adjusted such that they ranged from weights of one to 10 maintaining the same relationship to each other. Finally, only those issues concerned with radiological matters, and their respective importance weights, were considered in the scores.

Issue and Factor Selection

In order to identify the issues and factors by which the waste disposal technologies were to be judged, Texas (TRCR Parts 45 and 21) and federal regulations (10 CFR 61 and 10 CFR 20) which form the basis for many design considerations were examined. Principal requirements of these regulations include:

- The annual radiation dose for any member of the public may not exceed certain limits.
- Efforts must be made to keep releases of radioactive materials "as low as reasonably achievable".
- Protection must be provided against inadvertent intrusion into the disposal facility.
- Operations must be conducted to keep occupational radiation exposures low.
- The facility must be designed to minimize long-term maintenance.
- The facility must be physically stable for 500 years.

In addition to these regulatory aspects, social, political, and economic aspects were also considered in the selection process.

The issues and factors selected for use in the decision analysis are listed in Table II.

The issue and factor importance weights assigned by the public participants are listed in Table III. The performance ratings, by factor, for each of the eleven disposal technologies were combined with the importance weights to obtain the disposal technology scores.

TABLE II

ISSUES AND FACTORS USED IN DECISION ANALYSIS OF LOW-LEVEL RADIOACTIVE WASTE DISPOSAL TECHNOLOGIES

Issue	Factor
1. Radiation Safety to the General Public	1.1 Degree of Protection to Collective Populations 1.2 Degree of Protection to Critical Population Groups 1.3 Period of Total Containment 1.4 Uncertainty of Long-Term Safety Performance Assessments
2. Worker Safety	2.1 Worker Radiation Doses 2.2 Industrial Safety
3. Radiation Safety to Intruders	3.1 Protection of Inadvertent Intruders 3.2 Attractiveness to Inadvertent Intruders 3.3 Impacts to Scavengers 3.4 Security Against Scavengers
4. Economics and Cost	4.1 Unit Disposal Cost ($ per cubic foot) 4.2 Economic Benefit to Local Community 4.3 Economic Cost to Local Community
5. Remedial Action	5.1 Cost of Remedial Action 5.2 Radiation Exposures During Remedial Action 5.3 Expected Effectiveness of Remedial Action
6. Ease of Implementation	6.1 Regulatory Tools Available for Licensing 6.2 Uncertainty in Meeting Licensing Requirements
7. Operational Flexibility	7.1 Ability to Accept all Waste Forms and Packages 7.2 Disposal Operations Sequencing 7.3 Construction Activities Management
8. Post-Closure Stability	8.1 Period of Active Maintenance 8.2 Effectiveness Against Natural Disruptions
9. Impact on Local Community	9.1 Aesthetics of Facility 9.2 Number of People Working at Facility 9.3 Long-Term Cultural and Social Impacts
10. Site and Facility Considerations	10.1 Cost Effectiveness of Siting Facility 10.2 Feasibility of Siting Facility
11. Non-Radiological Environmental Impacts	11.1 Emissions From Facility 11.2 Impacts From Related Activities 11.3 Ease of Effluent Control

TABLE III

Issue and Factor Importance Weights Used in the Decision Analysis

Issue/Factor	Average
1. Radiation Safety to the General Public	10.0
1.1 Degree of Protection to Collective Populations	0.3
1.2 Degree of Protection to Critical Population Groups	0.4
1.3 Period of Total Containment	0.2
1.4 Uncertainty of Long-Term Safety Performance Assessments	0.2
2. Worker Safety	10.0
2.1 Worker Radiation Doses	0.5
2.2 Industrial Safety	0.5
3. Radiation Safety to Intruders	6.6
3.1 Protection of Inadvertent Intruders	0.2
3.2 Attractiveness to Inadvertent Intruders	0.2
3.3 Impacts to Scavengers	0.3
3.4 Security Against Scavengers	0.3
4. Economics and Cost	9.8
4.1 Unit Disposal Cost ($ per cubic ft)	0.3
4.2 Economic Benefit to Local Community	0.4
4.3 Economic Cost to Local Community	0.3
5. Remedial Action	6.4
5.1 Cost of Remedial Action	0.3
5.2 Radiation Exposures During Remedial Action	0.3
5.3 Expected Effectiveness of Remedial Action	0.4
6. Ease of Implementation	7.8
6.1 Regulatory Tools Available for Licensing	0.6
6.2 Uncertainty in Meeting Licensing Requirements	0.4
7. Operational Flexibility	7.9
7.1 Ability to Accept all Waste Forms and Packages	0.4
7.2 Disposal Operations Sequencing	0.2
7.3 Construction Activities Management	0.4
8. Post-Closure Stability	7.2
8.1 Period of Active Maintenance	0.6
8.2 Effectiveness Against Natural Disruptions	0.4
9. Impact on Local Community	9.7
9.1 Aesthetics of Facility	0.2
9.2 Number of People Working at Facility	0.3
9.3 Long-Term Cultural and Social Impacts	0.5
10. Site and Facility Considerations	9.2
10.1 Cost Effectiveness of Siting Facility	0.5
10.2 Feasibility of Siting Facility	0.5
11. Non-Radiological Environmental Impacts	7.9
11.1 Emissions From Facility	0.3
11.2 Impacts From Related Activities	0.5
11.3 Ease of Effluent Control	0.2

Disposal Technology Scores

Issue scores for all disposal technologies are presented in Table IV. Comparison of the issue scores for improved shallow land disposal and above-ground vault disposal reveals that shallow land disposal received scores which were at least 12 points higher than those for above-ground for four issues, with one issue score different by 25 points. Comparing below-ground vault disposal and above-ground vault disposal, below-ground vault scored at least 12 points higher for three issues (radiation safety to the public, east of implementation, and post-closure stability). Other disposal technologies had fewer extremes in issue scores.

The disposal technology scores are illustrated in Fig. 3. The uncertainty bars represent one standard deviation about the mean disposal technology score resulting from variation in factor performance ratings. For the purpose of this analysis, both issue and factor importance weights were considered invariant. The disposal technology scores appear to fall into three groups, between which the uncertainty bars about the technology scores do not overlap. Improved shallow land disposal and shallow land disposal rank highest, followed by a group of other below-ground disposal technologies with engineered enhancements. The lowest ranking group is comprised primarily of technologies within which some or all of the waste is placed above natural grade.

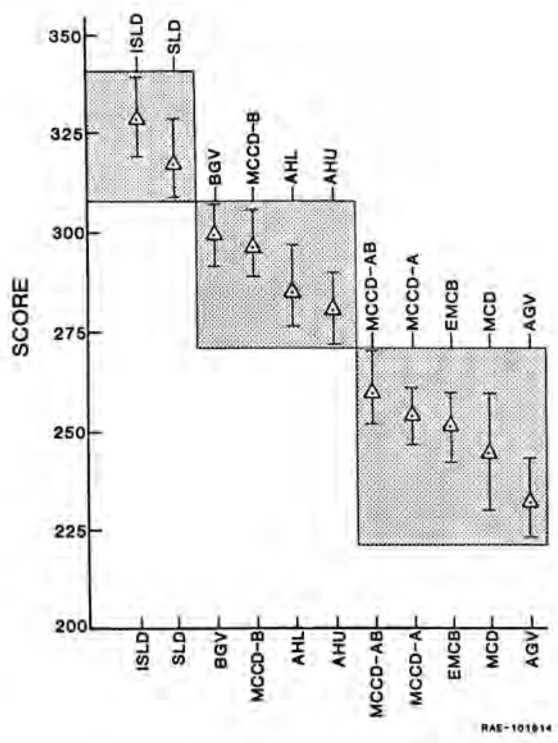

Fig. 3. Disposal Technology Scores from Decision Analysis Process.

The sensitivity of the total scores to changes in the issue importance weights was examined by considering three modifications to the original issue importance weights. In the first case, the range of

TABLE IV

Issue and Total Scores for Eleven Disposal Technologies

	Improved Shallow Land Disposal	Shallow Land Disposal	Below-Ground Vault Disposal	Below-Ground Modular Concrete Canister Disposal	Lined Augered Holes	Unlined Augered Holes	Above/Below-Ground Modular Concrete Canister Disposal	Above-Ground Modular Concrete Canister Disposal	Earth Mounded Concrete Bunker Disposal	Mined Cavity Disposal	Above-Ground Vault Disposal
Radiation Safety to the General Public	28	23	35	36	33	29	31	26	32	36	21
Worker Safety	40	40	33	28	33	33	27	26	25	19	27
Radiation Safety to Intruders	18	15	22	17	24	24	19	18	17	26	14
Economics and Costs	35	35	30	29	29	29	27	27	29	25	29
Remedial Action	18	18	22	18	16	15	22	23	18	11	24
Ease of Implementation	37	38	26	19	25	25	17	16	19	13	12
Operational Flexibility	35	35	23	18	19	21	21	22	18	21	22
Post-Closure Stability	22	19	22	18	25	25	21	24	18	29	10
Impact on Local Community	35	34	33	25	31	30	25	23	25	27	25
Site and Facility Considerations	31	32	29	29	25	25	29	30	29	13	29
Non-Radiologic Environmental Impacts	29	29	23	21	26	25	21	20	21	25	22
TOTAL	329	319	299	297	286	281	260	253	251	245	234

variation of the issue importance factors was expanded while preserving the same proportionate differences between various issue weights. This produced issue importance weights ranging from 1.0 to 10.0. This adjustment attempts to reflect sentiments expressed verbally by the non-technical participants that they considered certain issues to be far more important than others.

The second sensitivity case assumed all issues were equally important. The effect of this case is to permit the technical ratings to control the scores, without influence from the issue importance weights. The third sensitivity analysis allowed only the radiological safety issues (through their importance weights and performance ratings) to have any influence on the score. For these four issues, the original issue importance weights were used, while all others were set equal to zero.

The results of the sensitivity analyses are given in Table V, where only minor changes from the original disposal technology scores are noted. No changes in ranking were noted for the case of uniform issue weighting, although the magnitudes of the differences between technology scores did show some variation. For the analysis using adjusted issue weights, only two minor reversals in technology ranking were noted. The third and fourth-ranked technologies (below-ground modular concrete canisters and below-ground vaults) switched ranking as did above-ground modular concrete canisters and earth mounded concrete bunkers. While the separation between technologies varied slightly, no other changes in rank were noted.

Consideration of only radiological issues produced much more noticeable changes in technology rankings. The enhanced below-ground technologies ranked highest, followed by shallow land disposal and improved shallow land disposal. Those technologies in which some or all of the waste is placed above natural grade tended, once again, to be among the lowest ranked technologies.

TABLE V

Sensitivity of Disposal Technology Scores to Issue Importance Weights

Disposal Technology	Scores With Issue Importance Weights			
	Original Weights	Adjusted Weights	Uniform Weights	Radiological Issues Only With Original Weights
Improved Shallow Land Disposal	328	382	230	109
Shallow Land Disposal	318	370	224	98
Below-Ground Vault	299	352	210	113
Below-Ground Modular Concrete Canister Disposal	297	356	205	115
Lined Augered Holes	286	337	200	116
Unlined Augered Holes	281	331	195	111
Above/Below-Ground Modular Concrete Canister Disposal	260	310	181	99
Above-Ground Modular Concrete Canister Disposal	253	302	174	91
Earth Mounded Concrete Bunker	251	295	178	92
Mined Cavity Disposal	245	294	168	113
Above-Ground Vaults	234	275	164	72

SELECTION OF DISPOSAL TECHNOLOGIES FOR CONCEPTUAL INVESTIGATIONS

The results of the scoring process were used by the Authority, together with consideration of other information and constraints (such as radiological performance, economic performance, and legislative requirements), to select those disposal technologies which would receive further development and evaluation in the conceptual design process.

Based on the results of the decision making process, the advice of the Authority's Citizens Advisory Panel, and the staff's analysis of the available technologies and applicable law, three disposal technologies were selected for further analysis. These are:

- o Modular Concrete Canisters
- o Below-Ground Vaults
- o Above-Ground Vaults.

Above-ground vaults were selected to satisfy a legislative mandate to evaluate above-grade disposal methods. Modular concrete canister disposal was selected for below-ground disposal because of (1) the ability to maintain greater control over material quality in the fabrication (rather than the construction) setting, (2) greater operational flexibility, and (3) the relative ease of remedial action, if it becomes necessary. However, it was acknowledged that some waste packages and items might be too large or might be odd-shaped and not compatible with the canisters. Therefore, below-ground vaults were selected as a supplemental disposal method for those unusual waste items.

A third method used parts of the first two choices: above-ground modular concrete canisters placed over a small below-ground vault, with an earth tumulus. This disposal method is analogous to the earth mounded concrete bunker system utilized in France. It is more flexible because all waste is placed in modular concrete canisters, where the French system entombs the waste in a concrete monolith. This choice is desirable from a remedial action perspective, and will satisfy, at least in part, the desire for an above-ground disposal system.

In summary, the Authority identified four of the initial eleven disposal technologies to receive further development and assessment:

- o Below-ground modular concrete canisters
- o Below-ground vaults
- o Above/below-ground modular concrete canisters
- o Above-ground vaults.

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