Hazard Ranking System Issue Analysis: Review of Existing Ranking Systems

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ABSTRACT

This report presents the results of a review of two types of ranking systems: hazardous waste site ranking systems and chemical hazard ranking systems. This effort focused on identifying existing ranking systems for review and then reviewing the identified systems to determine whether they have features (e.g., parameters, methodologies) that warrant further evaluation with regard to possible modifications to the EPA Hazard Ranking System (HRS). Where further evaluation appears warranted, that evaluation is being conducted as part of companion studies to this effort, and the results of the evaluation will be presented in the reports on these companion studies, rather than in this report. The purpose of this report is solely to present an overview of the ranking systems that were reviewed and to identify those features that were deemed to warrant further study. Twenty-nine waste site ranking systems were identified and reviewed. Several of those systems contain features that should be evaluated in companion studies to this effort for possible adaptation and use in the HRS. Fifty-six chemical hazard ranking systems were identified. Twenty-four of these should be further evaluated in the companion toxicity analysis effort.

Suggested Keywords: Chemical Hazard Ranking Systems, Hazard Ranking Systems, Superfund, Waste Site Ranking Systems

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1.0 INTRODUCTION

1.1 Background

The Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) (PL 96-510) requires the President to identify national priorities for remedial action among releases or threatened releases of hazardous substances. These releases are to be identified based on criteria promulgated in the National Contingency Plan (NCP). On July 16, 1982, EPA promulgated the Hazard Ranking System (HRS) as Appendix A to the NCP (40 CFR 300; 47 FR 31180). The HRS comprises the criteria required under CERCLA and is used by EPA to estimate the relative potential hazard posed by releases or threatened releases of hazardous substances.

The HRS is a means for applying uniform technical judgment regarding the potential hazards presented by a release relative to other releases. The HRS is used in identifying releases as national priorities for further investigation and possible remedial action by assigning numerical values (according to prescribed guidelines) to factors that characterize the potential of any given release to cause harm. The values are manipulated mathematically to yield a single score that is designed to indicate the potential hazard posed by each release relative to other releases. This score is one of the criteria used by EPA in determining whether the release should be placed on the National Priorities List (NPL).

During the original NCP rulemaking process and the subsequent application of the HRS to specific releases, a number of technical issues have been raised regarding the HRS. These issues concern the desire for modifications to the HRS to further improve its capability to estimate the relative potential hazard of releases. The issues include:

- Review of other existing ranking systems suitable for ranking hazardous waste sites for the NPL.
- Feasibility of considering ground water flow direction and distance, as well as defining "aquifer of concern," in determining potentially affected targets.
- Development of a human food chain exposure evaluation methodology.
- Development of a potential for air release factor category in the HRS air pathway.
- Review of the adequacy of the target distance specified in the air pathway.
- Feasibility of considering the accumulation of hazardous substances in indoor environments.
- Feasibility of developing factors to account for environmental attenuation of hazardous substances in ground and surface water.
- Feasibility of developing a more discriminating toxicity factor.
- Refinement of the definition of "significance" as it relates to observed releases.
- Suitability of the current HRS default value for an unknown waste quantity.
- Feasibility of determining and using hazardous substance concentration data.

- Feasibility of evaluating waste quantity on a hazardous constituent basis.
- Review of the adequacy of the target distance specified in the surface water pathway.
- Development of a sensitive environment evaluation methodology.
- Feasibility of revising the containment factors to increase discrimination among facilities.
- Review of the potential for future changes in laboratory detection limits to affect the types of sites considered for the NPL.

Each technical issue is the subject of one or more separate but related reports. These reports, although providing background, analysis, conclusions and recommendations regarding the technical issue, will not directly affect the HRS. Rather, these reports will be used by an EPA working group that will assess and integrate the results and prepare recommendations to EPA management regarding future changes to the HRS. Any changes will then be proposed in Federal notice and comment rulemaking as formal changes to the NCP. The following section describes the specific issue that is the subject of this report.

1.2 Issue Description

Since the enactment of CERCLA in 1980, a variety of ranking systems have been developed to rate the relative threat posed by hazardous waste sites or by hazardous substances. Some of these ranking systems may contain features (e.g., parameters, methodologies) that could be adapted for use in the HRS to address some of the issues identified above. Consequently, these ranking systems need to be examined as a first step in resolving these issues. Even where the review does not identify features that could be adapted for use in the HRS, it may still identify some concepts from these other systems that could be further developed to resolve various issues.

1.3 Scope and Approach

This paper presents the results of the review of the existing ranking systems. Two types of ranking systems were examined: waste site ranking systems and chemical hazard ranking systems. Waste site ranking systems rank the relative threat (or risk) posed by waste sites. Chemical hazard ranking systems rank the relative hazard (or risk) posed by waste streams or individual waste constituents, considering the environmental media (e.g., air, water) in which exposure may occur.

The ranking systems to be examined under this effort were identified primarily through a literature review and also through contacts with other Federal agencies (e.g., National Oceanic and Atmospheric Administration, Department of Defense). In addition, the ten EPA Regional Offices were contacted to identify ranking systems used by the States within each region. As specified in the work statement, individual States were not surveyed. However, where a State system was identified by the above review, the State was contacted if necessary to obtain a description of the system.

Each identified waste site ranking system has been reviewed to determine who is using the system, what it is being used for, who developed the system, and how it both resembles and differs from the HRS with regard to such features as parameters, methodologies, procedures, and applications. The objective of this review is to identify important differences in the features of these systems that warrant further evaluation with regard to developing options for possible modification of the HRS.

Where further evaluation of a feature is warranted, that evaluation is being conducted as part of the companion HRS issue analysis task appropriate to the specific feature being examined. For example, parameters or methodologies applicable to the evaluation of human food chain effects are being examined as part of the effort to develop a human food chain exposure evaluation methodology. Therefore, the results of such evaluations are presented in the appropriate issue analysis report, rather than in this report. The purpose of this report is solely to present an overview of these other waste site ranking systems and to identify those features of the systems that warrant further study.

Since the chemical hazard ranking systems pertain only to one issue analysis effort (i.e., the development of a more discriminating HRS toxicity factor), the intent in this report is just to identify such systems for review under the toxicity issue analysis effort.

They are not being examined to identify which of their features warrant further review under the toxicity issue analysis effort.

1.4 Organization of the Report

Section 2 contains the results of the review of the existing ranking systems, including recommendations on the features of the existing systems that warrant further evaluation in the other HRS issue analyses efforts. Section 3 presents the bibliography. Appendix A provides an overview of the current HRS. Appendix B contains the summary reviews of 29 existing waste site ranking systems. Appendix C presents a brief summary of the 56 chemical hazard ranking systems identified.

2.0 RESULTS OF THE REVIEW

This chapter presents the results of the review of the existing ranking systems. The discussion is divided into two sections: the first addresses waste site ranking systems, the second addresses chemical hazard ranking systems. The emphasis in the discussion of waste site ranking systems is on the overall comparison of these systems to the HRS and the identification of the features of these systems that should be evaluated further in various HRS issue analysis tasks. The emphasis in the discussion of the chemical hazard ranking systems is on the identification of such systems for further review.

2.1 Waste Site Ranking Systems

Table 1 presents a list of the 29 waste site ranking systems examined, together with the system acronyms used in this report. The following sections discuss the current status of each system, the migration pathways addressed by each system, and the features of each system that warrant further evaluation.

2.1.1 Status of Each System

This section discusses the current status of the 29 ranking systems identified in Table 1. Of the 11 Federal ranking systems, 9 are currently being used by Federal agencies and 2 (DRASTIC and RAPS) are being tested prior to use.

Two of the EPA systems (RCRA Risk-Cost Analysis Model and the Liner Location Risk and Cost Analysis Model) are being used by EPA

TABLE 1

LIST OF WASTE SITE RANKING SYSTEMS EXAMINED

FEDERAL WASTE SITE RANKING SYSTEMS

- EPA Waste Site Ranking Systems
  - DRASTIC
  - Liner Location Risk and Cost Analysis Model (LLRCAM)
  - RCRA Risk-Cost Analysis Model (WET Model)
- Other Federal Waste Site Ranking Systems
  - Centers for Disease Control System for Prevention, Assessment and Control of Exposures and Health Effects from Hazardous Sites (S.P.A.C.E. for Health)
  - National Oceanic and Atmospheric Administration (NOAA)
  - Department of Energy Modified Hazard Ranking System (mHRS)
  - Department of Energy Remedial Action Priority System (RAPS)
  - Department of the Air Force Hazard Assessment Rating Methodology (HARM)
  - Department of the Air Force Hazard Assessment Rating Methodology (HARM II)
  - Department of the Interior Impact Scoring Methodology (ISM)
  - Department of the Navy Confirmation Study Ranking System (CSRS)

STATE WASTE SITE RANKING SYSTEMS

- California Public Health Benefit/Cost Ranking System (PHBCRS)
- Connecticut (CT)
- Illinois Rating Scheme (IRS)
- Massachusetts Prioritization of Environmental Risks and Control Options (PERCO) System
- Michigan Site Assessment System (SAS)
- New Hampshire (NH)
- New Jersey Severity Index (NJ)
- New York Human Exposure Potential Ranking Model (HEPRM)

OTHER WASTE SITE RANKING SYSTEMS

- Arthur D. Little, Inc. (ADL)
- Dames and Moore Rating and Risk Assessment Methodology (RRAM)
- Hagerty, Pavoni, and Herr (HPH)
- JRB Associates, Inc. (JRB)
- The LeGrand System (LeGrand)

TABLE 1 (Concluded)

OTHER WASTE SITE RANKING SYSTEMS (Concluded)

- Monroe County, NY, Monroe County Methodology (MCM)
- Olivieri and Eisenberg Assessment Methodology (OEAM)
- Phillips, Nathwani, and Mooij Matrix (PNMM)
- Rating Methodology Model (RMM)
- TRC Environmental Consultants, Inc. Objective Calculation Procedure (OCP)

program offices for various regulatory and policy analysis purposes. The third EPA system, DRASTIC, is currently being tested prior to being finalized. (Several EPA program offices are also developing systems that currently include elements of the draft version of DRASTIC.)

The three Department of Defense systems (HARM, HARM II, and CSRS) are used to assign priorities to hazardous substance sites for further study and possible remedial action under the DOD-wide Installation Restoration Program. The Centers for Disease Control (CDC) System (S.P.A.C.E. for Health) was developed for use in public health assessments of hazardous sites. It is used to assign a priority to a site based on the potential of the site to endanger human health. NOAA applies its system to sites that have previously been scored with the HRS. It is used to identify for further review the areas under NOAA's purview that are threatened by wastes sites. The DOI system is used to assist in establishing priorities for addressing problems associated with abandoned mine land, such as polluted water, subsidence, dangerous highwalls, and flooding due to clogging of streams by mine sediments. The DOE modified HRS is currently being used in ranking waste sites at DOE facilities. RAPS has recently been completed and will soon be tested by DOE, prior to use in assigning priorities to DOE mixed (e.g., hazardous nonradioactive and radioactive) waste sites for further study and possible remedial action.

Six of the eight State systems examined are currently in use. A seventh, PERCO, has recently been completed and is currently being evaluated by Massachusetts for possible implementation. An eighth, HEPRM, is still being developed for use in New York. Like the Federal agencies, the States use their systems to rank sites for further investigation or for remedial action. This is generally done to supplement the HRS rankings.

In addition to the Federal and State systems, ten systems developed and/or used by other governmental and nongovernmental entities were examined. Of these, only two (Monroe County Methodology and the Olivieri and Eisenberg Assessment Methodology) are currently known to be in use and are discussed below. Portions of two other systems (JRB and LeGrand) have, however, been adapted for use in several other systems that are also currently in use. For example, factors contained in the JRB system have been adapted for use in the HRS, HARM, HARM II, and CSRS. Factors contained in the LeGrand System have been adapted for use in the Connecticut System and the Olivieri and Eisenberg Assessment Methodology.

The Monroe County Methodology (MCM) is used by Monroe County, New York to assist in identifying and prioritizing sites that may contain hazardous substances for further investigation. It is intended to be used prior to the application of systems, such as the HRS, that require site inspection data. The Olivieri and Eisenberg Assessment Methodology is used by the San Francisco Regional Water

Quality Control Board to rank wastes sites in terms of their relative potential for ground water contamination.

2.1.2 Pathways Considered by Each System

Table 2 presents an overview of the migration and hazard pathways addressed in each system. The HRS addresses three migration pathways and two additional hazard pathways: ground water, surface water, air, direct contact, and fire and explosion (see Appendix A). Only two other systems examined (PERCO and HEPRM) address more pathways, while most of the other systems address fewer pathways. Five systems also incorporate one or more migration and hazard pathways not present in the HRS. These pathways include overland water flow, flooding, toxic vapors, soil ingestion, and aquatic biota ingestion.

Additionally, one system (HEPRM), and possibly one other (RAPS), distinguish between migration pathways and modes of exposure by considering inter-media transfers of contaminants.* (The available documentation on RAPS does not, however, describe how this is done.) One other system (HARM II) considers inter-media transfers from

*The term "migration pathway" generally refers to the medium through which the contaminants in question migrate, e.g., ground water, surface water, air. In contrast, the term "mode of exposure" refers to the pathway through which the contaminants enter the human (or other) body or otherwise effect the environment. Examples of modes of exposure include ingestion, inhalation, or dermal contact. Inter-media transfer refers to the movement of a contaminant from one medium, through an interface, into another medium (e.g., volatilization of a substance from contaminated water into the atmosphere where it may be inhaled).

TABLE 2

MIGRATION AND HAZARD PATHWAYS REFLECTED IN EACH SYSTEM EXAMINED*

	Ground Water	Surface Water	Air	Direct Contact	Fire and Explosion	Other
EPA Waste Site Ranking Systems						
HRS	X	X	X	X	X	
DRASTIC	X					
LLRCAM	X	X	X			
WET Model	X	X	X			
Other Federal Systems						
S.P.A.C.E. for Health	X	X	X			X
NOAA		X				
mHRS	X	X	X			
RAPS	X	X	X			X
HARM	X	X				
HARM II	X	X				
ISM	NA	NA	NA	NA	NA	NA
CSRS	X	X				
State Waste Site Ranking Systems						
PHBCRS	X	X	X	X	X	
CT	X	X	X			
IRS	X					
PERCO	X	X	X	X	X	X
SAS	X	X	X	X	X	
NH	NA	NA	NA	NA	NA	NA
NJ	NA	NA	NA	NA	NA	NA
HEPRM	X	X	X	X		X
Other Waste Site Ranking Systems						
ADL	X	X	X			
RRAM	X	X				
HPH	X					
JRB	X	X				
LeGrand	X					
MCM	X					
OEAM	X					
PNMM	X					
RMM	X	X				
OCP	X	X	X			X

*A blank indicates that the system does not address that pathway. NA means that the system does not consider migration and hazard pathways.

ground water to surface water in counting ground water targets in those situations where such a transfer is suspected to occur or can be confirmed. The other systems, including the HRS, either make no distinctions at all, or implicitly link migration pathways and modes of exposure. For example, these latter systems consider only the ingestion of contaminated water for the ground water pathway. No provision is made, for example, to reflect any inhalation exposure arising, in part, from the release of volatile substances during ground water transport or use. At least one recent study (Foster and Chrostowski, 1986) has indicated that the inter-media transfer from water to air could pose a threat to individuals for certain indoor water uses (e.g., showering).

2.1.3 System Features that Warrant Further Evaluation

Table 3 identifies the major characteristics of each waste site ranking system reviewed (see Appendix B for a more detailed description). The table also identifies the features of each system that warrant further evaluation in the other issue analysis efforts. These include:

- Hydrogeologic factors (such as sorption, conductivity, and type of media).
- Food chain and bioaccumulation factors.
- Toxicity factors (including carcinogenicity factors).
- Population at risk factors.
- Site size factors (such as exposed area).
- Potential for flooding factors.

TABLE 3

SUMMARY OF THE RESULTS OF THE REVIEW OF EXISTING WASTE SITE RANKING SYSTEMS

SYSTEM	MAJOR CHARACTERISTICS	GENERAL CONCLUSIONS
EPA Waste Site Ranking Systems		
DRASTIC	• Ranks sites based on their hydrogeologic potential for ground water contamination • Not a risk ranking system • Employs seven hydrogeologic factors	• Evaluate four factors not currently in HRS: - Aquifer media - Soil media - Topography - Hydraulic conductivity
Liner Location Risk And Cost Analysis Model	• Designed to estimate chronic risks, cost/risk and cost/effectiveness implications of different land disposal technologies • Intended as a policy analysis model, not a ranking system • Not meant for site-specific comparisons among facilities	• Not applicable for ranking the relative threat posed by CERCLA sites • If sufficient data were available for CERCLA sites, some of the modeling approaches embodied in the system might be applicable to the development of a risk-based ranking system
RCRA Risk-Cost Analysis Model (WET Model)	• Designed to evaluate risk and cost aspects of different waste management practices applied to different waste streams • Intended as a policy analysis model, not a ranking system • Not meant for site-specific applications	• Not applicable for ranking the relative threat posed by CERCLA sites • If sufficient data were available for CERCLA sites, some of the modeling approaches embodied in the system might be applicable to the development of a risk-based ranking system
Other Federal Waste Site Ranking Systems		
S.P.A.C.E. for Health (CDC)	• Designed to aid in preventing and controlling health problems associated with hazardous sites • Contains a scheme for assigning priorities to a site based on the of a site potential to endanger human health	• Examine concept of using reports of human health effects at a site in the ranking of the site

TABLE 3 (Continued)

SYSTEM	MAJOR CHARACTERISTICS	GENERAL CONCLUSIONS
<u>Other Federal Waste Site Ranking Systems</u> (Continued)		
S.P.A.C.E. for Health (CDC) (Concluded)	• Employs four categories: - Site characteristics - Exposure potential (for five migration pathways) - Potential for human exposure - Health effects in the population • Method for combining factor scores to derive site scores is left up to user	
NOAA	• Designed to assign priorities, for further review, to waste sites that threaten resources under trusteeship of NOAA • Used after HRS ranking has been completed • Not a risk ranking system • Based on three indices: - Proximity Index - Resource Index - Chemical Index	• Review Proximity Index and Resource Index for possible use in food chain exposure method
Modified Hazard Ranking System (mHRS) (DOE)	• Identical to HRS except in method used to evaluate toxicity factor for radionuclides	• Evaluate method used in rating radionuclide toxicity • Review concept of maximum possible exposure concentration for use in evaluating waste characteristics
Remedial Action Priority System (RAPS) (DOE)	• Risk ranking system based on estimated exposure concentrations and associated health risks • Addresses four migration pathways: - Overland flow - Ground water - Surface water - Air	• Review migration pathways to identify any factors and approaches that could be adapted for used in HRS

TABLE 3 (Continued)

SYSTEM	MAJOR CHARACTERISTICS	GENERAL CONCLUSIONS
Other Federal Waste Site Ranking Systems (Continued)		
Remedial Action Priority System (RAPS) (DOE) (Concluded)	• Addresses four types of exposures: - Dermal - External radiation - Inhalation - Ingestion • Data requirements substantially exceed those of HRS	
Impact Scoring Methodology (DOI)	• Evaluates relative impacts of problems associated with abandoned mine land	• No further evaluation warranted
Hazard Assessment Rating Methodology (HARM) (USAF)	• Used to rank sites for further investigation based on equivalent of Preliminary Assessment information • Site score is average of three subscores (receptors, waste characteristics, and pathways) multiplied by a management practices score • Pathways score reflects potential for migration through ground water, surface water, or flooding • Subscores are not linked, i.e., surface water receptors may be averaged with ground water migration potential	• Evaluate concepts embedded in the following HARM factors: - Potential for flooding - Surface soil permeability (for surface water pathway) - Data quality/confidence
Hazard Assessment Rating Methodology-II (HARM II) (USAF)	• Used to rank sites for remedial investigation • Considers two pathways: - Ground water - Surface water • Pathway score based on: - Potential to release - Human health and ecological hazard potential - Population or resource at risk	• Evaluate human health and ecological hazard quotient and travel factors • Evaluate use of weighted root-mean-square algorithm in determining overall site score

TABLE 3 (Continued)

SYSTEM	MAJOR CHARACTERISTICS	GENERAL CONCLUSIONS
Other Federal Waste Site Ranking Systems (Concluded)		
Hazard Assessment Rating Methodology-II (HARM II) (USAF) (Concluded)	• Subscores produced for appropriate combinations of factors, e.g., surface water migration/human health effects • Site score is weighted root-mean-square of subscores	
Confirmation Study Ranking System (CSRS) (USN)	• Nearly identical to HARM • Primary differences between CSRS and HARM are in waste characteristics methodology, waste management practices scoring, and in use of product rather than average to calculate overall score	• Evaluate concepts embedded in the following factors not included in HRS: - Bioaccumulation potential - Time factors - Potential for flooding - Surface soil permeability (for surface water pathway)
State Waste Site Ranking Systems		
Public Health Benefit/ Cost Ranking System (California)	• Designed to rank site remedial action alternatives in terms of benefit/cost relationships • Benefit is defined as reduction in sum of HRS site migration, fire and explosion, and direct contact scores	• Identical to HRS, except for cost factor • No further evaluation is warranted
Connecticut	• Designed to classify sites as: - Posing no hazard - Requiring further investigation - Posing an imminent hazard • Sites are classified as posing an imminent hazard whenever any of the following conditions pertain: - Improperly disposed liquid PCB wastes - Asbestos that can become airborne - Improperly disposed pesticides - Contaminants disposed within 200 feet of a drinking water supply	• Evaluate concepts embedded in the sorption, gradient, and thickness factors

TABLE 3 (Continued)

SYSTEM	MAJOR CHARACTERISTICS	GENERAL CONCLUSIONS
State Waste Site Ranking Systems (Continued)		
Connecticut (Concluded)	- Possible fire or explosion - Fish kills - Discharge of hazardous materials to storm sewers or surface water • Rating system applies only to potential for ground water contamination, using factors based on an adaptation of original LeGrand system (see below)	
Rating Scheme (Illinois)	• Screening tool to assist in regional planning • Evaluates relative human health threat posed by sites from ground water contamination • Four factors are evaluated, each consisting of several elements: - Health risk of waste and handling mode - Population at risk - Proximity of waste activity to public water supply wells or potable aquifer - Aquifer susceptibility • Site score is normalized sum of factors scores	• Evaluate population at risk factor • Other factors not appropriate for use in HRS
Prioritization of Environmental Risks and Control Options (PERCO) (Massachusetts)	• Designed to rank sites based on chronic and episodic hazards to human health and the environment, providing a rationale for allocating remedial action funds • Four pathways are assessed for chronic hazard: - Air - Ground water - Surface water - Soil/direct contact • Episodic hazards consist of fire and explosion, toxic vapor, and floods • Basic measure of interest is the population/resources exposed to "critical" levels of contamination • Concentration data (at least one sample) for the site being rated or from sites similar to the site being rated must be available in order to rate the site	• Evaluate four concepts: - Use of health effects benchmarks - Use of data from sites similar to the site being rated - Use of simplified air dispersion equations to specify distance rings for rating the air target population - Use of a flooding factor

TABLE 3 (Continued)

SYSTEM	MAJOR CHARACTERISTICS	GENERAL CONCLUSIONS
State Waste Site Ranking Systems (Continued)		
Site Assessment System (SAS) (Michigan)	• Multi-pathway ranking system designed to reflect the relative risk posed by sites to public health and environmental resources • Five exposure pathways are reflected: - Ground water - Surface water - Air - Direct contact - Fire and explosion • Site score calculated as the square root of the sum of the squares of the pathway scores plus a pathway-independent chemical hazard score • Pathway score is the sum of a potential exposure score and an existing exposure score • Chemical hazard score is evaluated based on the following factors: - Toxicity (acute, subchronic, chronic, ecological and genotoxicity) - Bioaccumulation potential - Persistance - Flammability - Reactivity - Data uncertainty	• Evaluate the chemical hazard rating methodology
New Hampshire	• System designed to rank hazardous wastes sites as high, medium, or low priority • All NPL sites are assigned a high priority • System includes factors for carcinogenic potential and exposure potential • Presumably, the score is based on the maximum carcinogenic potential for the substances at the site	• Evaluate method for scoring carcinogenic potential

TABLE 3 (Continued)

SYSTEM	MAJOR CHARACTERISTICS	GENERAL CONCLUSIONS
State Waste Site Ranking Systems (Continued)		
Severity Index (New Jersey)	• Tool to assist in ranking sites for site inspections based on data from a preliminary assessment • Severity index score is product of a waste characteristics score and an exposure potential score • Exposure potential considers six exposure media (e.g., ground water, air, fire/explosion), population density/sensitive environments, and observed exposures • Waste characteristics consider toxicity/persistence, waste quantity, and containment	• No further evaluation warranted.
Human Exposure Potential Ranking Model (HEPRM) (New York)	• System being developed to prioritize sites for further investigative and remedial actions based on their potential to impact human health • Scores developed for 40 potential human exposure pathways, e.g., ingestion of surface water • Each exposure pathway score is the product of four factors - Chemical factor - Target factor - Probability of release factor - Weighting factor	• Evaluate the exposure pathways not already considered in the HRS, such as soil ingestion and aquatic biota ingestion

TABLE 3 (Continued)

SYSTEM	MAJOR CHARACTERISTICS	GENERAL CONCLUSIONS
State Waste Site Ranking Systems (Concluded)		
Human Exposure Potential Ranking Model (HEPRM) (New York) (Concluded)	• Each of the above four factors are based on other factors which vary according to pathway being scored • Exposure pathways are grouped into four media: - Air - Soil - Ground water - Surface Water • Score for each medium is the sum of appropriate exposure pathway scores • Site score is sum of the medium scores	
Other Waste Site Ranking Systems		
Arthur D. Little, Inc.	• Developed as a modification of the HRS • Addresses three pathways: ground water, surface water, and air • Site score is the sum of the pathway values • Three factor categories are evaluated within each pathway: - Health effects - Waste reaching pathway - Population exposed • Health effects category is based on toxicity of the contaminants on the site • "Waste reaching pathway" category is evaluated based on evidence of release in all pathways or, alternately, on "route characteristics" in ground water and surface water pathways • Population exposed category is very similar to HRS targets category • Overall pathway score is the product of category values.	• ADL system was assessed during the development of the HRS • No further evaluation is warranted

TABLE 3 (Continued)

SYSTEM	MAJOR CHARACTERISTICS	GENERAL CONCLUSIONS
Other Waste Site Ranking Systems (Continued)		
Rating and Risk Assessment Methodology (Dames and Moore)	• Adaptation of JRB Associates, Inc. methodology (see below) • Uses same four rating categories, with some additions and deletions • Each category is classified as low or high risk • Overall site classification based on rating category classifications • Six site classifications ranging from very low risk to very high risk	• No further evaluation warranted
Hagerty, Pavoni, and Herr System (HPH)	• Intended to rate potential ground water impacts from landfilling of wastes • System produces two separate rankings based on: - Waste characteristics - Site and target characteristics • Five factors from the PHL model (see Table 5) are used to rank waste characteristics • Ten factors are used to rank potential of a landfill to impact ground water	• No further evaluation warranted
Methodology for Rating the Hazard Potential of Waste Disposal Sites (JRB model or Rating Methodology Model)	• Consists of 31 rating factors grouped into 4 areas: - Receptors - Pathways - Waste characteristics - Waste management practices • Each rating factor is scored on a scale of 0 to 3 and then multiplied by a factor-specific multiplier • Overall site score is normalized sum of factor scores	• JRB model was assessed during the development of the HRS • No further evaluation is warranted

TABLE 3 (Continued)

SYSTEM	MAJOR CHARACTERISTICS	GENERAL CONCLUSIONS
Other Waste Site Ranking Systems (Continued)		
The LeGrand System (LeGrand)	• Designed to evaluate the acceptability of a proposed disposal site based on the potential for ground water contamination at the site • Evaluation process provides for human judgment • System produces a vector of site characteristics • Site characteristics are based on the following factors: - Distance between contamination source and water supply - Depth to water table - Water table gradient - Permeability-sorption - Confidence in accuracy of results - Miscellaneous identifiers • One additional factor is developed based on: - Degree of aquifer sensitivity (type of underlying material) - Degree of contaminant severity (either source of the waste or type of waste) • Vector adjusted according to a baseline to form a situation rating • Situation rating is used to qualitatively assess the probability of contamination and the degree of acceptability of the site	• Evaluate concepts embedded in the permeability-sorption factor, the aquifer sensitivity factors and the water table gradient factor • Evaluate concept for including a qualitative assessment of the accuracy of the rating results
Monroe County Methodology (MCM)	• Intended as an initial step in identifying and ranking sites for further investigation • Sites are identified and classified into six site activity categories: - Identifiable - Possible - Unspecified - Lagoons - Auto junkyards and salvage areas - Suspicious	• Evaluate geologic ranking system

TABLE 3 (Continued)

SYSTEM	MAJOR CHARACTERISTICS	GENERAL CONCLUSIONS
Other Waste Site Ranking Systems (Continued)		
Monroe County Methodology (MCM) (Concluded)	• Geologic ranking is prepared, based on the following factors: - Overburden geology - Estimated permeability - Relief/geomorphology - Depth to ground water - Ground water gradient - Bedrock character - Soil properties - Texture and behavior • Sites that could impact nearby wells are immediately referred to authorities for testing • Other sites are assigned a priority using a matrix for ranking geologic and land use impact, size, and type of activity	
Olivieri and Eisenberg Assessment Methodology	• Ranks organic solvent hazardous wastes sites in terms of relative potential for ground water contamination • Corresponds to the HRS ground water pathway • Sites are ranked with regard to two areas: - Site sensitivity - Contamination severity • Site sensitivity rates the susceptibility of the site to ground water contamination using 14 hydrogeologic and water use factors in four factor categories based on LeGrand • Contamination severity rates the severity and potential for release from the site to contaminate ground water using nine factors in three factor categories (four of the factors are based upon the Michigan Site Assessment System)	• Factors warrant further evaluation

TABLE 3 (Continued)

SYSTEM	MAJOR CHARACTERISTICS	GENERAL CONCLUSIONS
Other Waste Site Ranking Systems (Continued)		
Olivieri and Eisenberg Assessment Methodology (Concluded)	• The scores for each factor are summed to give site sensitivity and contaminant severity ratings • Overall site scoring method is user specific, usually taken as sum of factor scores	
Phillips, Nathwani, and Mooij Matrix (PNM Matrix)	• Designed to rank potential ground water impacts from the land disposal of wastes • The PNM matrix produces three types of rankings: - Waste hazardousness ranking - Soil-site ranking - Combined waste-soil-site ranking • Ten factors (four of which are modified from the PHL model summarized in Table 5) are used to rank the relative hazardousness (in ground water) of wastes that might be land disposed • The six factors not included in the PNL model that are used to rank waste hazardousness are: - Chemical persistence - Sorption - Viscosity - Solubility - Acidity/basicity - Waste application rate • Seven other factors (six of which are modified from the LeGrand Model) and an infiltration factor are used to rank the potential of a land disposal site to result in impacts to ground water • The 17 factors are combined in a matrix to rank the waste-soil-site interaction	• Factors in PNM matrix are not adequately defined for inclusion in the HRS • No further evaluation is warranted

TABLE 3 (Concluded)

SYSTEM	MAJOR CHARACTERISTICS	GENERAL CONCLUSIONS
Other Waste Site Ranking Systems (Concluded)		
Rating Methodology Model	• Developed based on the JRB model • Designed to evaluate the risk of hazardous waste sites and to produce a single score reflecting this risk • Incorporates four types of factors: receptors, pathways, waste characteristics, and waste management practices • Scores are determined for each of several evaluation parameters then multiplied by weighting factors to form site parameter scores • These scores are summed and normalized to form a site score.	• No further evaluation is warranted
Objective Calculation Procedure (OCP)	• Calculation equation designed to estimate the total risk from a waste site over a defined time period • Equation reflects the potency of chemicals released, the relationship between ambient concentrations of the chemicals and the ingestion/inhalation rates of the chemicals, population and the exposure concentration	• No further evaluation is warranted

2.2 Chemical Hazard Ranking Systems

As stated earlier, the principal objective in reviewing chemical hazard ranking systems is to identify systems for more comprehensive review in the toxicity issue analysis effort (DeSesso et al., 1986). A total of 56 chemical hazard ranking systems have been identified and are listed in Table 4.

Fifty-two of these systems were identified from two comprehensive reviews of chemical hazard ranking systems (Environ Corporation, 1984 and Hushon and Kornreich, 1984). These two reviews examined 23 and 34 systems respectively; 5 systems were duplicated within the two sets of reviews.

To illustrate the different approaches that have been used to rate chemical hazards among the various systems and to illustrate the types of systems that are and are not being recommended for review in the toxicity issue analysis effort, 7 of the 56 identified systems are briefly reviewed in this report (see Appendix C). The major characteristics of these 7 systems and the conclusions from the review are presented in Table 5.

As indicated in Table 5, four of these seven systems should be evaluated further:

- CERCLA Reportable Quantities (RQ)
- Clement Associates, Inc.
- RCRA Hazardous Waste Scheduling Methodology
- Superfund Public Health Evaluation (SPHE) System

TABLE 4

LIST OF IDENTIFIED CHEMICAL HAZARD RANKING SYSTEMS

EPA Chemical Hazard Ranking Systems	EC*	HK	B	C
Action Alert System	X			X
CERCLA Reportable Quantities (RQ) System				X
RCRA Hazardous Waste Scheduling Methodology				X
Superfund Public Health Evaluation (SPHE) System				X
Selected Criteria Processing	X			
Assessment of Air Emissions from Hazardous Waste Treatment, Storage and Disposal	X			
The RCRA Risk-Cost Analysis Model	X	X	X	
Toxicity Scoring System Using RTECS Data Base	X			
Integrated Environment Management Program	X			
OTS Chemical Scoring System	X			
Pesticide Manufacturing Air Prioritization		X		
Index of Exposure		X		
System for Rapid Ranking of Environmental Pollutants		X		
TSCA-ITC Scoring System Workshop		X		
Scoring of Organic Pollutants		X		
ITC Scoring for Biological Effects		X		
ITC Scoring for Exposure		X		
OECD Ecotoxicology Testing Scheme		X		
Chemical Scoring System Development		X		
Environmental Scoring of Chemicals		X		
Ordering of Commercial Chemicals on NIOSH Suspected Carcinogens List		X		
Other Federal Chemical Hazard Ranking Systems				
U.S. Army Hazard Multi-Media Estimating and Ranking Scheme	X			
U.S. Army System for Setting Priorities for R&D on Army Chemicals		X		
U.S. Coast Guard		X		
Consumer Product Safety Commission (CPSC)		X		
National Science Foundation		X		
National Cancer Institute		X		
OTA		X		

*EC: Reviewed in Environ Corporation, 1984
HK: Reviewed in Hushon and Kornreich, 1984
B: Also reviewed in Appendix B
C: Reviewed separately in Appendix C

TABLE 4 (Concluded)

Other Federal Chemical Hazard Ranking Systems (Concluded)	EC*	HK	B	C
NIOSH National Occupational Hazard Survey		X		
NIOSH Identification of High Risk Occupation Groups and Industrial Processes		X		
State Chemical Hazard Ranking Systems				
Alaska	X			
California	X			
California Air Resources Board		X		
Louisiana	X			
Maryland	X			
Michigan	X	X		
Rhode Island	X			
Washington	X			
Foreign Chemical Hazard Ranking Systems				
EEC Ranking Algorithm for Water Pollutants	X	X		
UNEP		X		
Federal Republic of Germany		X		
French Ministere de l'Environment		X		
Other Chemical Hazard Ranking Systems				
Barring Model	X	X		X
Clement Associates				X
PHL Model	X	X		X
Chemical Manufacturers Association	X			
Dow Chemical	X			
Soap & Detergent Association	X			
American Paper Institute and National Forest Products Association	X			
National Paint and Coatings Association	X			
Weyerhauser Corporation	X			
Eastman Kodak Company		X		
ASTM, Committee D-19		X		
Flavor and Extract Manufacturer's Association		X		
Hooker Chemical		X		
R. Squire		X		

*EC: Reviewed in Environ Corporation, 1984
HK: Reviewed in Hushon and Kornreich, 1984
B: Also reviewed in Appendix B
C: Reviewed separately in Appendix C

TABLE 5

SUMMARY OF THE RESULTS OF THE REVIEW OF SELECTED EXISTING CHEMICAL HAZARD RANKING SYSTEMS

SYSTEM	MAJOR CHARACTERISTICS	GENERAL CONCLUSIONS
Action Alert System (AAS)	• Developed as a preliminary screening tool for use in assigning priorities to chemicals for further study or regulatory action based on the potential risk they pose to humans and aquatic life, based upon partial information about their presence in the environment and the associated potential hazards • Screening provides either a qualitative indication of the degree of concern warranted for each chemical or a specification of the additional data required to make such a determination	• AAS is not applicable to ranking the potential threat posed by hazardous waste sites • No further evaluation is warranted
Barring Model	• Designed to identify a representative list of hazardous substances and to rank the effects of these substances in terms of air, water, and land pollution hazards • Total effects rating (TER) calculated as weighted sum of four factor values: - Toxic effects to human and other populations - Flammable hazard - Explosive hazard - Reactive hazard • Hazard extent rating (HER) based on annual production and consumer distribution of the hazardous substances • Hazard rating = TER x HER	• Considered in the development of more recent ranking models • No further evaluation warranted
CERCLA Reportable Quantities (RQ) System	• Determines the minimum quantity of a hazardous substance spill or release that must be reported to EPA under CERCLA • Substance assigned an interim RQ for each for the following charateristics: - Reactivity - Ignitability - Acute toxicity - Aquatic toxicity - Chronic toxicity	• System should be evaluated further

TABLE 5 (Continued)

SYSTEM	MAJOR CHARACTERISTICS	GENERAL CONCLUSIONS
CERCLA Reportable Quantities (RQ) System (Concluded)	• Statutory RQ is minimum of interim RQs adjusted to account for persistence of the substance in the environment • Reactivity is evaluated based on the ability of the substance to react with water and/or itself • Ignitability is evaluated based on the flash point and boiling point of the substance • Acute toxicity is evaluated based on the LC_{50} or LD_{50} of the substance administered by ingestion, inhalation or dermal contact, as applicable • Aquatic toxicity is evaluated using the LC_{50} of the substance • Chronic toxicity is evaluated based on a overall minimum effective dose (MED) of the substance and numerical assessment of the severity of the effects caused by repeated or continuous expsoure	
Clement Associates, Inc.	• The methodology provides a score for a pollutant that represents the relative probability that a given hazard will occur in exposed populations per unit dose of the pollutant • Effects scored for each pollutant are carcinogenicity, teratogenicity, reproductive toxicity, mutagenicity, hepatotoxicity, renal toxicity, neurobehavioral toxicity and effects in other organ systems • The score is a product of two measures of risk: - Probability that the pollutant is toxic to humans, based on inferences from animal data, or on direct measures of human toxicity - Probability of occurrence of the toxic effect in exposed humans per unit dose of exposure, assuming that the agent is a human toxicant	• System should be evaluated further

TABLE 5 (Continued)

SYSTEM	MAJOR CHARACTERISTICS	GENERAL CONCLUSIONS
PHL Model	• Designed to rank the hazardousness of substances placed in landfills • The model consists of five ranking factors that are summed: - Toxicity (based on Sax) - Ground water toxicity - Disease transmission potential - Biodegradability - Mobility • Computational equations are used to assign a value to each factor	• Considered in the development of more recent ranking models • No further evaluation is warranted
RCRA Hazardous Waste Scheduling Methodology	• Ranks the toxic potential of waste constituents • Incorporates measures of both acute and chronic toxicity: - LD_{50} is used as a measure of acute toxicity - Chronic toxicity designated as Equivalent Dose Estimate (EDE) • EDE based on acceptable daily intakes (ADIs) for noncarcinogens and unit cancer risks (UCRs) for carcinogens, modified as necessary by uncertainty factors • For compounds with extremely limited data bases, EDEs are assigned by analogy to structurally similar compounds or are estimated by applying a large standardization factor to a measure of acute toxicity • Constituent score is the sum of the chronic toxicity score (0 to 9) plus the acute toxicity score (1, if acute toxicity is high, 0 otherwise)	• System should be evaluated further
Superfund Public Health Evaluation (SPHE) System	• Method for estimating the public health impacts of NPL sites • Method for selecting indicator chemicals was examined as a chemical hazard ranking system	• Approach to deriving toxicity constants should be evaluated further

TABLE 5 (Concluded)

SYSTEM	MAJOR CHARACTERISTICS	GENERAL CONCLUSIONS
Superfund Public Health Evaluation (SPHE) System (Concluded)	• Uses an "indicator score" to identify indicator chemicals; this is the product of the measured (or estimated) concentration of the chemical at the site times a "toxicity constant" (in units of inverse concentration) • Separate toxicity constants for carcinogenic and noncarcinogenic effects • Acute toxicity not considered • Noncarcinogenic toxicity factors based on quotient of minimum effective dose (MED) and severity factor (RV_e) • Carcinogenic toxicity constants based on effective dose to 10 percent of exposed population • Other factors considered subjectively include: - Persistence - Weight of evidence for carcinogenicity - Water solubility - Vapor pressure - Henry's constant - Organic carbon partition coefficient	

All of these four systems, except the SPHE system, address acute toxicity. All but the RQ system address carcinogenic effects. All four address chronic noncarcinogenic effects. The RQ system assigns a relative ranking value to hazardous substances based on several hazard characteristics including toxicity, reactivity, and ignitability. The Clement Associates, Inc. system assigns a relative risk ranking to chemicals that represents the relative probability that a given hazard (e.g., cancer) will occur in exposed populations per unit dose of the chemical. The RCRA system ranks chemicals for acute toxicity based on their LD_{50}* and for chronic toxicity based on their acceptable daily intake or unit cancer risk, as applicable. The SPHE system assigns an indicator score to chemicals based on chronic toxicity, distinguishing between carcinogens and noncarcinogens, using a methodology based in part on the RQ system. (See Appendix C for more details about these systems.)

The other three systems reviewed (Action Alert, Barring Model, PHL Model) were found not to warrant further study. The Action Alert System is designed as a planning tool for qualitatively ranking chemicals for further study or regulatory action based on the potential risk they pose to humans and to aquatic organisms. It is not intended to rank the relative hazard of the various chemicals. The Barring and PHL Models are very early ranking systems that were

*The LD_{50} represents the dose of a substance that is lethal to 50 percent of the test population.

considered in the development of more recent chemical hazard ranking models and do not warrant any further evaluation.

In addition, 20 of the 23 systems contained in the Environ Corporation review (1984) warrant further evaluation. The 3 that do not warrant further evaluation are those 3 discussed above. None of the 34 systems contained in the Hushon and Kornreich review (1984) warrant further evaluation. Many of these latter 34 systems are designed solely as screening tools for use in assigning priorities to chemicals, especially new chemicals or suspected carcinogens, for further study. They are not meant for, nor are they applicable to, rating the relative hazard of chemicals for use in regulatory programs. Most of the other systems within this set of 34 are intended to select or identify chemicals for regulation or control based on such factors as production rates and use patterns.

It should be noted that many of the waste site ranking systems reviewed in Appendix B also contain factors to rate chemical hazard. Those systems whose chemical hazard rating factors warrant further evaluation (e.g., Michigan Site Assessment System, U.S. Air Force HARM II System) are identified in Appendix B.

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APPENDIX A

OVERVIEW OF EPA HAZARD RANKING SYSTEM

The Hazard Ranking System (HRS) is used by EPA to estimate the relative potential hazard posed by releases or threatened releases of hazardous substances. The HRS migration score, which is described below, is one of the criteria used in determining whether the release or threatened release should be placed on the National Priorities List. This appendix presents an overview of the HRS. A more detailed description appears as Appendix A to the National Contingency Plan (40 CFR 300) and in the Federal Register (47 FR 31180, July 16, 1982).

The HRS addresses three hazard modes: migration, fire and explosion, and direct contact. The latter two are not used in computing the migration site score which is a criteria for placement on the NPL, but are included in the HRS as indicators of the need for emergency response. The migration mode consists of three potential migration pathways representing the major routes of environmental transport common to hazardous wastes sites: ground water, surface water, and air. Each route is structured similarly using three factor categories: release, waste characteristics, and targets.

The release category reflects the likelihood that the site has, is, or will release contaminants to the environment. If available monitoring data indicate that the site is releasing contaminants, then an "observed release" has been demonstrated.* If no such observed release can be demonstrated, then the release category is evaluated using route characteristics and containment factors. These factors are largely physical characteristics of the sites and their surrounding environments. It is important to note that the ground water and surface water routes contain factors for route characteristics while the air route does not. This permits sites to be evaluated for their potential to release contaminants to these two pathways in cases where documentation of a release is lacking. The current HRS requires that ambient air monitoring data support the conclusions that the site is, or has been, emitting contaminants before the site can receive a nonzero air route score.

The waste characteristics category reflects the implicit hazard of the contaminants that have been or might be released. The factors included in the waste characteristics categories address qualitative and quantitative characteristics of the wastes and waste contaminants found on the sites. The targets category constitutes a measure of the population and resources that might be adversely affected by a release. The factor categories and the factors contained in them are illustrated in Table A-1.

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*Information other than ambient monitoring data can be used to establish an "observed release" in certain situations. These situations are addressed on a case-by-case basis.

TABLE A-1

HRS RATING FACTORS

Factor Category	Route		
	Ground Water	Surface Water	Air
Release Category	Monitoring data or Depth to aquifer of concern Net precipitation Permeability Physical state Containment	Monitoring data or Facility slope and terrain Rainfall Distance to receiving water Physical state Containment	Monitoring data
Waste Characteristics	Toxicity/persistence Waste quantity	Toxicity/persistence Waste quantity	Reactivity/incompatibility Toxicity Waste quantity
Targets	Ground water use Distance/population	Surface water use Distance/population Distance to sensitive environment	Land use Distance/population Distance to sensitive environment

Within each route, the site is assigned a value for each applicable factor. The factor values are then multiplied by weighting factors and summed within factor categories. The resulting factor category values are then multiplied and normalized to form a migration route score. Thus, for each site, three migration route scores are produced, each on a scale of 0 to 100. These route scores are as follows:

- Ground water (S_{gw})
- Surface water (S_{sw})
- Air (S_a)

The overall site migration score (S_m) is then calculated as the root mean square (RMS) of the route scores:

$$S_m = (1/1.73)[(S_{sw})^2 + (S_{sw})^2 + (S_a)^2]^{1/2}$$

The RMS procedure was chosen to emphasize the highest scoring route while giving some consideration to secondary and tertiary routes. This procedure is illustrated in Figure A-1.

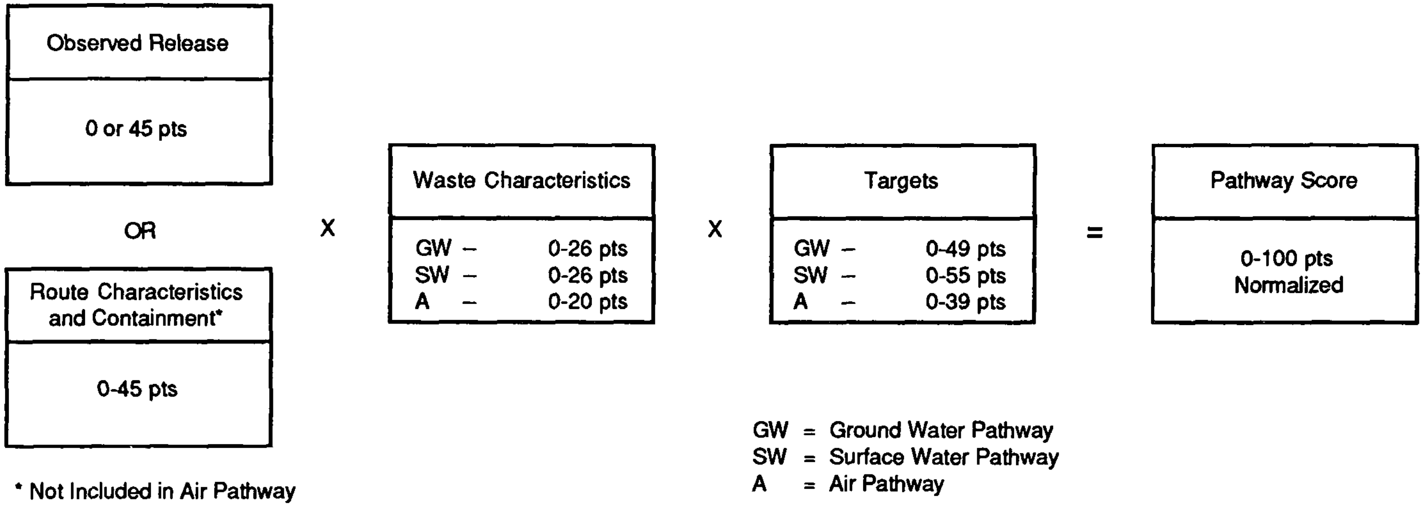


FIGURE A-1
BASIC HRS STRUCTURE

APPENDIX B

WASTE SITE RANKING SYSTEMS

This appendix summarizes 29 systems developed for use in ranking waste sites. Table 1 in Section 2 lists the systems reviewed. The summary presented for each system in this appendix contains information on the following topics:

- Name
- User
- Developer
- Use/Status
- General Description
- Similarities to HRS
- Differences from HRS
- Conclusions
- References

The appendix is divided into four sections:

B.1 EPA Waste Site Ranking Systems
B.2 Other Federal Waste Site Ranking Systems
B.3 State Waste Site Ranking Systems
B.4 Other Waste Site Ranking Systems

B.1 EPA Waste Site Ranking Systems

This section contains summaries of three EPA ranking systems:

- DRASTIC
- Liner Location Risk and Cost Analysis Model
- RCRA Risk-Cost Analysis Model

SYSTEM: DRASTIC

USER: Developed for use by the U.S. Environmental Protection Agency

DEVELOPER: National Water Well Association

USE/STATUS: DRASTIC is intended to be used to evaluate the relative vulnerability of areas to ground water contamination. A draft version of DRASTIC was completed in May 1985 and is currently being tested in 10 counties nationwide. Several EPA program offices (e.g., underground storage tanks) have implemented systems based on the draft version of DRASTIC.

GENERAL DESCRIPTION: DRASTIC is designed to evaluate the relative ground water pollution potential of any hydrogeologic setting or area. DRASTIC uses seven rating factors to compute an index (the DRASTIC Index) which indicates the relative vulnerability of an area to ground water contamination. The seven rating factors are as follows:

- Depth to Water (D)
- Net Recharge (R)
- Aquifer Media (A)
- Soil Media (S)
- Topography (slope) (T)
- Impact of the Vadose Zone (I)
- Hydraulic Conductivity of the Aquifer (C)

Each factor is assigned a weight based on its relative importance with regard to its pollution potential. The DRASTIC Index is calculated by multiplying the value assigned to a rating factor by its weight and summing the resulting value for the seven factors.

SIMILARITIES TO HRS: DRASTIC is intended to evaluate relative ground water pollution potential. As such it corresponds to the HRS ground water route characteristics category. Three of the

DRASTIC (Concluded)

SIMILARITIES TO HRS: (Concluded)

DRASTIC rating factors are similar to factors present in the HRS ground water route characteristics category:

- Depth to Water
- Net Recharge
- Impact of Vadose Zone

The scoring and weighting of these factors differ, however, from the HRS.

DIFFERENCES FROM HRS:

DRASTIC is not intended to evaluate the relative threat posed by a waste site since it does not consider waste characteristics, waste containment, or targets. Further, DRASTIC addresses only the potential for ground water contamination, ignoring the potential for surface water, air, and soil contamination. The following four of the DRASTIC rating factors do not correspond to any factors present in the HRS ground water route characteristics category:

- Aquifer Media
- Soil Media
- Topography
- Hydraulic Conductivity of the Aquifer

CONCLUSIONS:

The rating factors in DRASTIC need to be further evaluated for possible inclusion in the HRS.

REFERENCE:

U.S. Environmental Protection Agency, DRASTIC: A Standardized System for Evaluating Ground Water Pollution Potential Using Hydrogeologic Settings, (EPA-600/2-85/018), Robert S. Kerr Environmental Research Laboratory, Ada, OK, May 1985.

Thornhill, Jerry, U.S. Environmental Protection Agency, Ada, OK, personal communication to Carol Burger, The MITRE Corporation, September 19, 1986.

LINER LOCATION RISK AND COST ANALYSIS MODEL

SYSTEM: Liner Location Risk and Cost Analysis Model

USER: U.S. Environmental Protection Agency, Office of Solid Waste

DEVELOPER: Sobotka & Co., ICF, Inc., Environ Corp., Pope-Reid Associates, Inc., and Geraghty & Miller

USE/STATUS: The model is intended only for internal EPA use. It is available through the EPA National Computer Center and is currently being used by several EPA program offices. Portions of the model are still being evaluated. The model also is currently being revised for use in evaluating municipal landfills.

GENERAL DESCRIPTION: The Liner Location Risk and Cost Analysis Model is designed to investigate cost/risk and cost/effectiveness implications of the land disposal of hazardous wastes under different technology, location, and waste stream scenarios. The model estimates the relative chronic risk to human health from land disposal facilities with different design technology, location, and waste stream characteristics. The model also estimates the cost of facilities with differing technologies and sizes. The model uses a series of submodels to predict contaminant releases, subsurface and atmospheric transport, human exposure, and health risks based upon dose-response factors. The model embodies both numerous simplifying assumptions (e.g., homogeneous and isotropic aquifers) and generic parameters (e.g., generic ground water flow fields, generic well distances, generic contaminant mobility classes, generic design technologies).

SIMILARITIES TO HRS: The Liner Location Risk and Cost Analysis Model is not similar to the HRS. The only common characteristics are that both address waste disposal, relative risk, and two common pathways (air and ground water).

DIFFERENCE FROM HRS: There are considerable differences between the two systems. First, the liner location model is not a ranking system. It is primarily a policy analysis model. Second, it is not meant for site-specific comparisons among facilities, nor can it be easily adapted for such site-specific use. Third, it directly calculates relative risk using a process modeling approach and some generic configurations.

CONCLUSION: The Liner Location Risk and Cost Analysis Model is not applicable to the task of ranking CERCLA sites. The approaches embodied in the model could, however, be employed in developing a relative risk-based ranking system, providing sufficient data for use in such an approach were available for CERCLA sites.

REFERENCES:

U.S. Environmental Protection Agency, Liner Location Risk and Cost Analysis Model, (Draft Report), U.S. Environmental Protection Agency, January 1985.

Rothenstein, Cliff, U.S. Environmental Protection Agency, Washington, DC, personal communication to Carol Burger, The MITRE Corporation, September 22, 1986.

RCRA RISK-COST ANALYSIS MODEL

SYSTEM: RCRA Risk-Cost Analysis Model, also known as the WET Model

USER: Economic Analysis Branch, Office of Solid Waste, U.S. Environmental Protection Agency

DEVELOPER: ICF Incorporated

USE/STATUS: Currently used by the EPA Office of Solid Waste in assessing policies developed under RCRA.

GENERAL DESCRIPTION: The WET model is designed to evaluate waste management practices in the U.S. as an aid to the development of regulations under RCRA. The model produces relative risk and cost estimates for different management configurations of waste streams; waste transportation, treatment and disposal technologies; and environments (hence the acronym Waste, Environment, Technology). The model estimates human health, ecosystem and sensory risks from steady state releases of RCRA contaminants (and selected other contaminants) to ground water, surface water and air. The model also calculates the costs of each technology in a management configuration as an annual revenue requirement. The model treats each management configuration in a generic fashion employing standard risk assessment methods (e.g., emissions estimates coupled with transport and fate models aligned with dose response models) and numerous simplifying assumptions.

SIMILARITIES TO HRS: The WET model is not similar to the HRS. Nearly the only common characteristics is that both address waste disposal, relative risk, and the same three pathways.

DIFFERENCES FROM HRS: There are considerable differences between the two systems. First and most important, the WET model is not a ranking system. It

DIFFERENCES FROM HRS: (Concluded)

is a policy analysis model. Second, the WET model is not a site-specific model nor can it be easily adapted for site-specific use. Finally, the model apparently assumes that the generic sites are designed and operated according to RCRA promulgated or proposed regulations. Very few CERCLA sites would fit this assumption.

CONCLUSIONS:

The WET model is not applicable to the task of ranking CERCLA sites. The approaches embodied in the model could be employed in developing a relative risk-based ranking system, providing sufficient data for use in such an approach were available for CERCLA sites.

REFERENCES:

ICF Incorporated, The RCRA Risk-Cost Analysis Model Phase III Report, ICF Incorporated, Washington, DC, March 1, 1984.

ICF Incorporated, The RCRA Risk-Cost Analysis Model Phase III Report Appendices, ICF Incorporated, Washington, DC, March 1, 1984.

Males, Eric, "RCRA Risk-Cost Analysis Model," Presented at the AIChE Conference held on August 21, 1984, U.S. Environmental Protection Agency, Washington, DC, 1984.

B.2 Other Federal Waste Site Ranking Systems

This section contains summaries of eight systems developed by Federal agencies other than EPA for use in ranking sites for investigation and possible remedial action. The systems examined are as follows:

- S.P.A.C.E. for Health (CDC)
- National Oceanic and Atmospheric Administration Method
- mHRS (DOE)
- RAPS (DOE)
- HARM (USAF)
- HARM II (USAF)
- ISM (DOI)
- CSRS (USN)

CENTERS FOR DISEASE CONTROL

SYSTEM:	System for Prevention, Assessment, and Control of Exposures and Health Effects from Hazardous Sites (S.P.A.C.E. for Health)
USER:	Centers for Disease Control (CDC)
DEVELOPER:	Centers for Disease Control
USE/STATUS:	Used by CDC in support of public health assessments of hazardous sites.
GENERAL DESCRIPTION:	The S.P.A.C.E. for Health system was developed by CDC to assist State and local health official in preventing and controlling health problems associated with hazardous sites, including hazardous wastes sites. The system contains a prioritization scheme. The purpose of the scheme is to assign a site priority based on the potential of the site to endanger human health. The scheme is based on four factors: site characteristics, exposure potential of five pathways, potential for human exposure/absorption, and health effects in the population. The elements contained in these factors are listed in the Table B-1. The method for combining the score for each element to form a site score is left to the discretion of the analysts using the scheme. The scoring of the various elements is recommended to be done by a team of experts that includes at a minimum an environmental specialist, a toxicologist, and a physician and/or epidemiologist.
SIMILARITIES TO HRS:	Both are value-based systems addressing most of the same environmental pathways. Both are designed to make effective use of available information, without requiring extensive new information collection. Several of the elements in S.P.A.C.E. for Health have been excerpted directly or adapted from the HRS (e.g., toxicity, persistence, containment, waste quantity, ground water, surface water).

TABLE B-1

FACTORS AND ELEMENTS ADDRESSED IN THE S.P.A.C.E FOR HEALTH SYSTEM

FACTORS	ELEMENTS
Site Characteristics	Documentation of presence of hazardous substances Toxicity of five most hazardous substances at site Quantity of five most hazardous substances at site Persistence of five most hazardous substances at site Concentrations of five most hazardous substances at site Site management and containment Potential for direct access to site
Exposure Potential of Environmental Pathways	Ground water Surface water Air Deposition in(on) soil off site Presence in food chain
Potential for Human Exposure/Absorption	Presence of potentially exposed population Basis of evidence for human exposure/ absorption Levels of substances through biological sampling
Health Effects in Exposed Population	Allegation/reports of health effects Results of clinical or epidemiologic studies conducted Expectation of a currently observable health effect Expectation of a future health effect Severity of public health impact of presumed health effect

DIFFERENCES FROM HRS: The differences between the two systems are significant. The most important difference between the two is that S.P.A.C.E. for Health makes use of health effects information for the population exposed around the site in the rating process. It uses clinical data and biological sampling data, as well as allegations/reports of health effects, in the rating of several elements under both the potential for Human Exposure/Absorption and Health Effects in Exposed Population factors. This type of information is not typically utilized in the HRS. S.P.A.C.E. for Health is also a more subjective system than the HRS, e.g., allegation/reports of health effects are assigned a score of one even if they are "vague, nonspecific, poorly characterized allegations." The system also depends more on expert judgment as indicated above. Further, the assessment of threat is based on five substances present at the site rather than on one as in the HRS. Finally, S.P.A.C.E. for Health does not contain an algorithm to calculate the overall site score from the element scores; the determination of the overall score is left to the user's discretion.

CONCLUSIONS: Several of the factors in S.P.A.C.E. for Health have been derived from the HRS and do not warrant any further evaluation. However, the concept of using human health effects information, particularly observed human health effects potentially associated with the site, warrants further evaluation. For example, the idea embodied in S.P.A.C.E. for Health of employing alleged and substantiated health effects information for the surrounding population to aid in prioritizing sites should be examined. This type of information is frequently the spur to site identification and initial assessment.

REFERENCES:

French, Jean G. et al., A System for Prevention, Assessment, and Control of Exposures and Health Effects from Hazardous Sites (S.P.A.C.E. for Health), Centers for Disease Control, Atlanta, GA, January 1984.

Kay, Robert L., Jr. and Chester L. Tate, Jr., "Public Health Significance of Hazardous Waste Sites," Proceedings of the Fifth National Conference on Management of Uncontrolled Hazardous Waste Sites, held on November 7-9, 1984 in Washington, DC, Hazardous Materials Control Research Institute, Silver Spring, MD, 1984, pp. 232-238.

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

SYSTEM:	Untitled
USER:	Ocean Assessments Division, National Oceanic and Atmospheric Administration (NOAA)
DEVELOPER:	Ocean Assessments Division, NOAA
USE/STATUS:	The system has been applied to sites that have previously been scored with the HRS. The purpose is to identify, for further study by NOAA, those sites that appear to pose a threat to resources under the trusteeship of NOAA (as defined by CERCLA).
GENERAL DESCRIPTION:	The system consists of three indices: Proximity Index, Resource Index, and Chemical Index. The Proximity Index is a measure of the frequency with which various concentrations of contaminants from a site would reach the resource. The Resource Index is a measure of the value and extent of utilization of the marine resource. The Chemical Index is a measure of the toxicity and persistence of the most hazardous substance that could migrate from the site.
SIMILARITIES TO HRS:	The Chemical Index is derived from the HRS toxicity/persistence factor.
DIFFERENCE FROM HRS:	While comparable to the HRS Surface Water Use Factor, the Resource Index emphasizes fishery and aquatic habitat uses rather than the broad range of activities addressed in the HRS. The Proximity Factor combines data on the concentration of contaminants in the resource with data on the frequency of release (e.g., flooding).
CONCLUSIONS:	The three indices are not intended to constitute a hazardous site ranking system. Rather they are intended to assist in assigning priorities to previously ranked sites for further review by NOAA. The Proximity Index and the Resource Index

CONCLUSIONS: (Concluded)

should be reviewed as part of any development of a food chain exposure methodology for the HRS. However, it is unlikely that they would be adequate for use in the HRS in their present form.

REFERENCES:

Ocean Assessments Division, Office of Oceanography and Marine Services, National Ocean Services, National Oceanic and Atmospheric Administration, Coastal Hazardous Waste Site Review, April 1984.

DEPARTMENT OF ENERGY - mHRS

SYSTEM: Modified Hazard Ranking System (mHRS)

USER: U.S. Department of Energy (DOE)

DEVELOPER: Battelle Pacific Northwest Laboratory (PNL)

USE/STATUS: The mHRS was developed for DOE. It is currently being used by a number of DOE facilities to rank the threat posed by waste sites.

GENERAL DESCRIPTION: The Modified Hazard Ranking System was developed by PNL for DOE to address the concern expressed by DOE that the HRS reflects only the chemical hazard of radioactive isotopes and neglects the hazard posed by the radiation from such isotopes. The mHRS works within the framework of the HRS dividing the Waste Characteristics components of the HRS pathways into two subcomponents for radioactive and chemical wastes. The chemical wastes subcomponent of the mHRS is identical to the HRS waste characteristics component. The radioactive waste subcomponent is more complex.

To use the mHRS, the analyst identifies the radionuclides present in the site and determines their "dose factor group." The assignment of a radionuclide to a dose factor group is based on a dose factor calculated using the ONSITE/MAXI1 program. The dose factor was calculated separately for each radionuclide of concern and mode of exposure (e.g., inhalation and ingestion). If concentration data are available (pCi/L) for the radionuclides, the radioactive waste value is read from a matrix table. The rows reflect dose factor groups, the columns reflect the ambient concentration and the entries give the rankings. If no concentration data are available, the maximum potential concentrations are calculated using simplified transport equations and then are used with the above table. These equations are used only for the

GENERAL DESCRIPTION: (Concluded)	ground water, surface water, direct contact, and fire and explosion routes. No provision is made for estimating potential concentrations for the air route.
SIMILARITIES TO HRS:	The mHRS is designed to be embedded within the HRS. With the exception of the radioactive waste characteristics scoring mechanism, the mHRS is identical to the HRS.
DIFFERENCES FROM HRS:	The only difference between the two systems is the radioactive waste characteristics scoring mechanism.
CONCLUSIONS:	The mHRS radioactive waste scoring mechanism should be evaluated for possible inclusion in the HRS. Also, the concept of using simplified transport equations to assess the maximum possible exposure concentration should be evaluated.

REFERENCES:

Napier, B. A. and K. A. Hawley, "A Ranking System for Mixed Radioactive and Hazardous Waste Sites," Proceedings of the Fifth DOE Environmental Protection Information Meeting, (CONF-841187), held at Albuquerque, NM, November 6-8, 1984, U.S. Department of Energy, Washington, DC, April 1985.

Hawley, K. A. and B. A. Napier, A Ranking System for Sites with Mixed Radioactive and Hazardous Wastes, (Comment Draft), Battelle Pacific Northwest Laboratory, Richland, WA, June 1985.

Katz, Sherry, U.S. Department of Energy, Germantown, MD, personal communication to Carol Burger, The MITRE Corporation, September 18, 1986.

DEPARTMENT OF ENERGY - RAPS

SYSTEM:	Remedial Action Priority System (RAPS)
USER:	Developed for use by the Department of Energy
DEVELOPER:	Battelle Pacific Northwest Laboratory (PNL)
USE/STATUS:	The system has been completed and will be tested on two facilities in the fall of 1986. Use by DOE facilities is reported to be anticipated in the spring of 1987.
GENERAL DESCRIPTION:	The Remedial Action Priority System (RAPS) is designed to assess the risk posed by mixed (radioactive and nonradioactive hazardous) waste sites and to prioritize the sites for further investigation and remedial action. RAPS employs relatively simple transport, transformation and fate models to assess the risks posed to sensitive receptors by releases of contaminants. Four transport and transformation pathways are covered in RAPS: overland water flow, air, surface water, and ground water. Four additional modes of exposure are also reflected in the system: external dermal contact, external radiation dose, inhalation, and ingestion. A hazard potential index is calculated for each pathway reflecting the risks associated with that pathway. Sites/pathway combinations are then ranked using appropriate hazard potential indices. The site pathway ranks are then combined to form an overall site rank. The details of these combinatorics are not discussed in the available reference documents.
SIMILARITIES TO HRS:	The only important similarity between RAPS and the HRS is that both address the ground water, surface water, and air pathways. Of lesser significance is that both utilize some of the same data but in different fashions.

DIFFERENCES FROM HRS: RAPS is very different from the HRS. RAPS is expressly designed to assess the relative risks posed by sites. It employs transport, transformation and fate models to relate the characteristics of the site to the risks posed to receptors of concern. In contrast, the HRS is a value-based ranking system that indirectly reflects risk.

CONCLUSIONS: RAPS should be reviewed in detail (when its documentation becomes available) to determine whether any of the modeling techniques used in it can be adapted for use in the HRS.

REFERENCES:

Whelan, G. et al., "Development of the Remedial Action Priority System: An Improved Risk Assessment Tool for Prioritizing Hazardous and Radioactive-Mixed Waste Disposal Sites," Proceedings of the Sixth National Conference on Management of Uncontrolled Hazardous Waste Sites, held on November 4-6, 1985 in Washington, DC, Hazardous Materials Control Research Institute, Silver Spring, MD, 1985, pp. 432-437.

Katz, Sherry, U.S. Department of Energy, Germantown, MD, personal communication to Carol Burger, The MITRE Corporation, September 18, 1986.

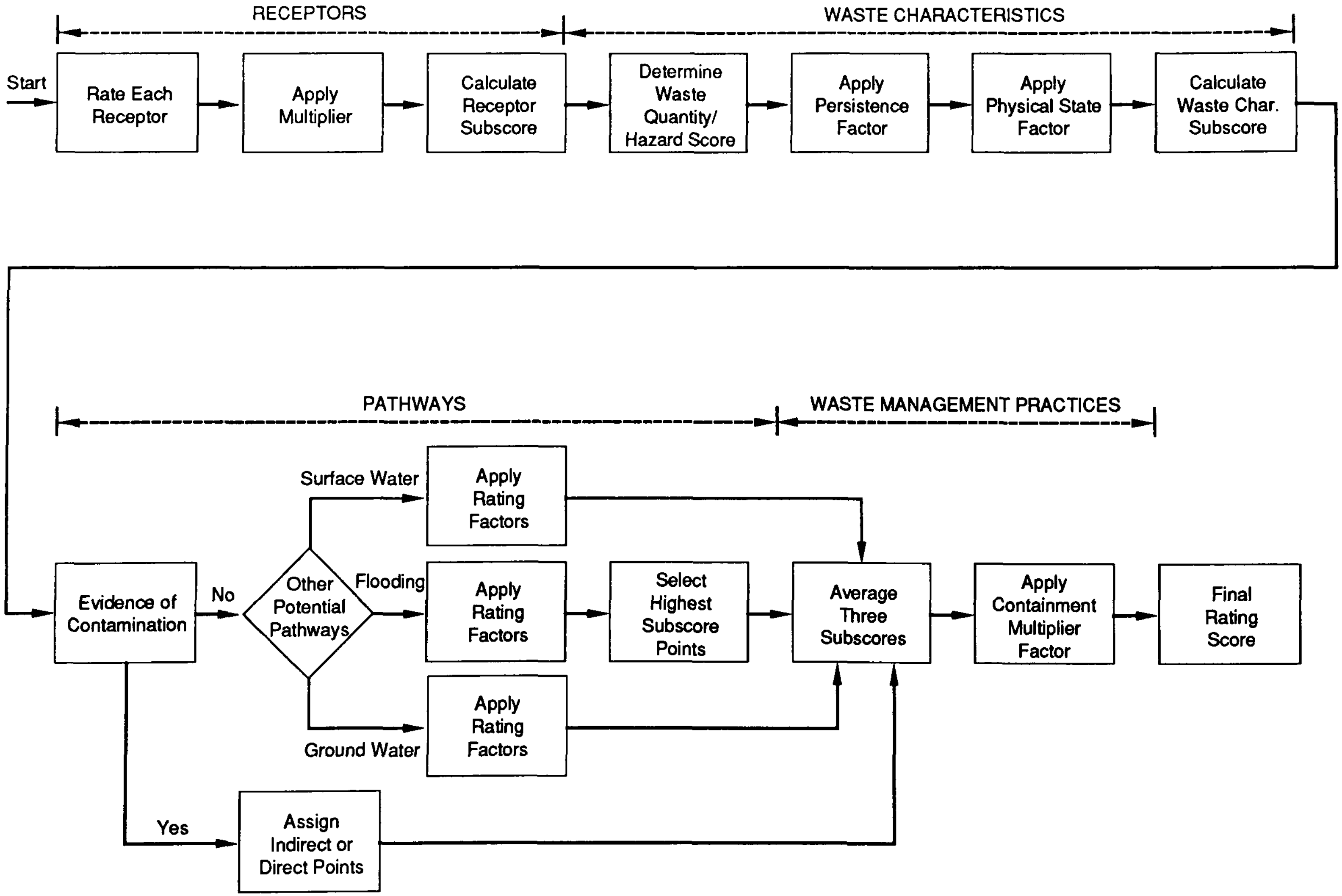
DEPARTMENT OF THE AIR FORCE - HARM

SYSTEM:	Hazard Assessment Rating Methodology (HARM)
USER:	U.S. Air Force (USAF) in the Installation Restoration Program (IRP)
DEVELOPER:	Jointly developed by the USAF Occupational Environmental Health Laboratory, Air Force Engineering Services Center, Engineering Science, and CH_2M Hill
USE/STATUS:	Used to rank sites for follow-up site investigations and confirmation activities under Phase II of the IRP.
GENERAL DESCRIPTION:	HARM is a site ranking system designed to rank sites for priority attention. The system is designed to use data developed during the Record Search (Phase I) portion of the IRP. Record Searches in the IRP are the near equivalent of the EPA Preliminary Assessments.

The overall procedure for developing a HARM site score is illustrated in Figure B-1. The HARM score is composed of four subscores reflecting the receptors potentially at risk, the waste and its characteristics present at the site, the potential migration pathways, and waste management practices at the site.

Table B-2 lists the rating factors and multipliers used to develop the receptors score. The overall receptor score is the normalized sum of the rating factor scores on a scale of 0 to 100.

The waste characteristics subscore is calculated as the product of a waste factor, a persistence factor and a physical state factor. The waste factor is evaluated using a matrix approach based on the quantity of wastes present, the level of confidence in the information, and the degree of hazard



Source: Engineering-Science, 1983.

FIGURE B-1
HAZARD ASSESSMENT RATING METHODOLOGY FLOW CHART

TABLE B-2

HARM RECEPTOR RATING FACTORS

Rating Factor	Multiplier
Population within 1,000 feet of site	4
Distance to nearest well	10
Land use/zoning within 1-mile radius	3
Distance to reservation boundary	6
Critical environments within 1-mile radius of site	10
Water quality of nearest surface water body	6
Ground water use of uppermost aquifer	9
Population served by surface water supply within 3 miles downstream of site	6
Population served by ground water supply within 3 miles of site	6

Source: Engineering-Science, 1983.

GENERAL DESCRIPTION: (Concluded)

posed by the wastes. The degree of hazard is the maximum of scores for toxicity, ignitability and radioactivity.

The pathway score is calculated as the maximum of a ground water migration potential score, a surface water migration potential score, a flooding score, a direct evidence of migration score, and an indirect evidence of migration score. The direct or indirect evidence of migration factors are assigned scores of 100 or 80, respectively, when applicable evidence indicates that migration has occurred. Otherwise, they are assigned scores of 0. The factors and multipliers used to evaluate surface water and ground water migration potential are listed in Table B-3. Each factor is evaluated on a scale of 0 to 3 and multiplied by the appropriate multiplier. The applicable factor scores are then summed and normalized to a scale of 0 to 100.

Waste management practices are evaluated using the following table:

- No containment: 1.0
- Limited containment: 0.95
- Fully contained and fully in compliance: 0.10

The overall site score is the average of the receptor score, the waste characteristics score and the pathways score multiplied by the waste management practices score.

SIMILARITIES TO HRS:

There are numerous similarities between HARM and the HRS. Both address ground water and surface water contamination. Both include provisions for assessing evidence of releases as well as potential for releases. Both also address the characteristics of the wastes present on the site and the targets (or receptors) potentially at risk from the site. Finally, the two systems have many

TABLE B-3

HARM PATHWAY POTENTIAL TO RELEASE FACTORS

Rating Factor	Multiplier
Surface Water Migration	
Distance to nearest surface water	8
Net precipitation	6
Surface erosion	8
Surface permeability	6
Rainfall intensity	8
Ground Water Migration	
Depth to ground water	8
Net precipitation	6
Soil permeability	8
Subsurface flows	8
Direct access to ground water	8
Flooding	1

Source: Engineering-Science, 1983.

SIMILARITIES TO HRS: (Concluded)

similar rating factors; however, the specific criteria for evaluating these rating factors are somewhat different in the two systems. The factors that are similar include:

- Size of target population
- Distance to nearest well
- Land use in potentially affected area
- Critical environments
- Water quality/use
- Waste quantity
- Contaminant persistence
- Physical state of wastes
- Distance to receiving stream
- Net precipitation
- Permeability
- Waste containment
- Rainfall intensity

DIFFERENCE FROM HRS:

Despite their similarities, HARM and the HRS are very different systems, both in terms of structure and purpose. Broadly speaking, the purpose of HARM is to rank sites for further investigation based on the equivalent of EPA preliminary assessment data. The HRS is designed to rank sites for further study and possible remedial action based on site inspection data (see also HARM II).

Further, the structures of the two systems are different. The HRS treats three migration pathways, evaluating each separately and then combining the migration route scores to from an overall site score using a root-mean-square approach. In contrast, HARM aggregates receptors and waste characteristics independent of migration pathway. Further, HARM addresses only migration via water pathways (i.e., ground water, surface water and flooding) and does not consider the air migration pathway. HARM also does not address the potential for direct contact with waste materials.

DIFFERENCE FROM HRS: (Concluded)

HARM also evaluates the overall site score differently from the HRS. HARM employs the average of the receptor, waste characteristics, and pathway scores, multiplied by the waste management practices, in contrast to the HRS which multiplies these scores and normalizes them to form pathway-specific scores. Overall, HARM evaluates a site based on the total of all potential targets, the most hazardous compound present on the site, the highest migration route score and the degree of waste management. Thus, in HARM, a site can achieve a high score for targets threatened by ground water contamination, using contaminants that cannot migrate through the ground water, based on their potential to migrate through surface water, modified by either ground water or surface water containment practices.

Finally, HARM contains some factors not included in the HRS:

- Potential for flooding
- Degree of surface erosion
- Subsurface flows (whether the bottom of site is located in the ground water)
- Potential for direct access to ground water (e.g., fractures, faults, faulty wall casings)
- Surface soil permeability (for the surface water pathway)
- Confidence in data on the wastes and waste quantity present on site

CONCLUSIONS:

The concepts embedded in the following HARM factors should be examined further (the factors themselves are generally not well enough defined for use in the HRS):

- Potential for flooding
- Surface soil permeability
- Data quality/confidence

DEPARTMENT OF THE AIR FORCE - HARM (Concluded)

REFERENCES:

Engineering-Science, Comparison of U.S. Air Force Hazard Assessment Rating Methodology (HARM) with U.S. Environmental Protection Agency Hazard Ranking System (HRS) at Four Air Force Bases Evaluated under the Phase I Installation Restoration Program, Engineering-Science, Atlanta, GA, April 1983.

Material from unpublished Air Force briefings.

DEPARTMENT OF THE AIR FORCE - HARM II

SYSTEM:	Hazard Assessment Rating Methodology II (HARM II)
USER:	U.S. Department of the Air Force (USAF)
DEVELOPER:	Oak Ridge National Laboratory (ORNL)
USE/STATUS:	HARM II is used by the USAF in their Installation Restoration Program (IRP) to assign priorities to sites for follow-up assessment and field studies.
GENERAL DESCRIPTION:	HARM II has been developed by ORNL as an extension of the HARM system. It is designed to make use of site-specific monitoring data. HARM is not designed to use such data. HARM II addresses two exposure pathways; ground water and surface water. Within each pathway, the site is assigned a score for potential to release contaminants (pathway score), human health and ecological hazard potential (contaminant hazards scores), and population or resources at risk (receptor scores). The various factors used in the scoring are listed in Table B-4. The system then produces a subscore for each appropriate combination of pathway score, contaminant hazards score, and receptors score, i.e., a surface water-health pathway score, a surface water-ecological pathway score, ground water-health pathway score, and surface water-ecological pathway score. These subscores are then combined using a weighted root mean square algorithm to form the site score.
SIMILARITIES TO HRS:	The principal similarities between HARM II and the HRS lie in the pathways common to both (surface water and ground water) and in the types of factors addressed by both. The specific factors used in HARM II are tailored to the needs of the USAF. The two systems

TABLE B-4

HARM II FACTORS

Surface Water

Pathway Score
- Contamination Detected
- Contamination Not Detected
  - Distance to nearest surface water
  - Net precipitation
  - Surface erosion potential
  - Rainfall intensity
  - Surface permeability
  - Flooding potential
- Containment Multiplier

Contaminant Hazards Score: Human Health
- Contaminants Detected
  - Log of sum of hazard quotients
- Contaminants Not Detected (based on single contaminant)
  - Toxicity
  - Bioaccumulation
  - Persistence
- Waste Quantity Multiplier

Receptors Score: Human Health
- Population that obtains drinking water from surface water sources within 3 miles downstream
- Water quality classification of surface water
- Population within 1,000 feet of site
- Distance to nearest installation boundary
- Land use/zoning within 1 mile

Contaminant Hazards Score: Ecological
- Contaminants Detected
  - Log of sum of hazard quotients
- Contaminants Not Detected
  - Toxicity
  - Persistence
- Waste Quantity Multiplier

Receptors Score: Ecological
- Importance/sensitivity of biota/habitats in surface water
- Importance/sensitivity of "critical environments" within 1 mile of site

TABLE B-4 (Continued)

Ground Water

Pathway Score
- Contamination Detected
- Contamination Not Detected
  - Depth to ground water from base of waste or contaminated zone
  - Permeability of unsaturated zone
  - Infiltration potential
  - Potential for discrete features to "short-circuit" pathway to water table
- Containment Multiplier

Contaminant Hazards Score: Human Health
- Contaminants Detected
  - Log of sum of hazard quotients
- Contaminants not detected
  - Toxicity
  - Bioaccumulation
  - Persistence
- Waste Quantity Multiplier

Receptors Score: Human Health
- Estimated mean ground water travel time to nearest downgradient well(s)
- Population served by affected aquifer(s) in downgradient direction within 3 miles
- Ground water use of uppermost aquifer
- Population served by affected aquifer(s) in downgradient direction within 3 miles
- Distance to nearest installation boundary
- Population within 1,000 feet of site
- Population served by affected aquifer(s) within 3 miles in other than downgradient direction
- Estimated mean ground water travel time to nearest downgradient surface water body that supplies water for domestic use or for food-chain agriculture
- Population served by affected water body within 3 miles downstream of discharge

Contaminant Hazards Score: Ecological
- Contaminants Detected
  - Log of sum of hazard quotients
- Contaminants not detected (based on single contaminant)
  - Toxicity
- Waste Quantity Multiplier

TABLE B-4 (Concluded)

Ground Water (Concluded)

Receptors Score: Ecological
- Estimated mean ground water travel time to downgradient habitat or natural area
- Importance/sensitivity of downgradient habitats/natural areas that are suspected discharge points
- Importance/sensitivity of "critical environments" within 1 mile of site

Source: Barnthouse et al., 1986.

SIMILARITIES TO HRS: (Concluded)

also multiply component scores to form subscores and then calculate the site score using root mean square algorithms.

DIFFERENCES FROM HRS:

There are several differences between HARM II and the HRS. The most apparent is that HARM II addresses only the ground water and surface water pathways. A further significant difference lies in the weighted root mean square (wRMS) algorithm used by HARM II in calculating the site score. HARM II calculates a subscore for each pathway-effects category combination. The wRMS algorithm assigns the pathway-human-health-effects subscores a weight of 5 while it assigns the pathway-ecological-effects subscores weight of 1. The HRS does not treat the pathway-effects combinations separately and effectively weights them equally. A second significant difference between the systems is the use of benchmarks for health effects, ecological effects and food chain accumulation in HARM II (the hazard quotients). This is in contrast to the use of the Sax toxicity index in the HRS. Finally, HARM II utilizes a number of factors not used in the HRS. The most significant of these are travel time and bioaccumulation potential. In part as a result of these inclusions, HARM II relies somewhat more on subjective judgment than does the HRS.

Barnthouse et al. (1986) list the following as the principal differences between the HRS and HARM II: omission of the air pathway, use of a standard four-point rating scale, inclusion of factors appropriate to USAF applications, assignment of difference values to individual factors, incorporation of additional site evaluation factors, and the wRMS algorithm.

CONCLUSIONS: HARM II contains a number of features that should be reviewed for possible inclusion in the HRS. Of particular interest are the hazard quotients used in assessing effects, the travel time used in assessing the score for receptors, the bioaccumulation factor, and the use of the wRMS algorithm.

REFERENCES: Barnthouse, L. W. et al., Development and Demonstration of a Hazard Assessment Rating Methodology for Phase II of the Installation Restoration Program, ORNL/TM-9857, Oak Ridge National Laboratory, TN, 1986.

DEPARTMENT OF THE INTERIOR

SYSTEM: Impact Scoring Methodology

USER: Office of Surface Mining, Department of the Interior

DEVELOPER: Office of Surface Mining, Department of the Interior

USE/STATUS: The Office of Surface Mining uses the impact scoring methodology to assist in establishing priorities for addressing problems associated with abandoned mine land.

GENERAL DESCRIPTION: The methodology is used to assign relative impact scores to the impacts resulting from abandoned mine land (AML) problems. AML problems include polluted water, subsidence, water problems such as recurrent flooding due to clogging of streams by mine sediments, and mine facility hazards such as open shafts, dangerous highwalls, and dangerous abandoned equipment. Impacts from these problems include injury and economic losses. There are two factors used to calculate an AML impact score. The first reflects the amount of potential economic loss or injury associated with the problem. The second reflects the frequency with which the loss or injury is likely to occur. The impact score for a problem is calculated by summing the value assigned to each factor. The cumulative impact score for an AML problem area is calculated as the weighted sum of the individual impact scores for each problem in the problem area.

SIMILARITIES TO HRS: The HRS and the impact scoring system are not comparable (see Differences).

DIFFERENCES FROM HRS: The HRS and the impact scoring system are not comparable in that they are intended to deal with entirely different types of problems. The HRS is intended to rank the relative threat of releases of hazardous

DIFFERENCES FROM HRS: (Concluded)	substances. The impact scoring methodology is intended to assign relative values to impacts of problems such as open shafts, abandoned equipment, and clogging of streams.
CONCLUSIONS:	The impact scoring methodology is not applicable to the ranking of hazardous substance release sites.
REFERENCE:	Tennessee Valley Authority and Oak Ridge National Laboratory, A National Inventory of Abandoned Mine Land Problems: An Emphasis on Health, Safety, and General Welfare Impacts, prepared for the Departments of Interior and Energy, 1983.

DEPARTMENT OF THE NAVY

SYSTEM: Confirmation Study Ranking System (CSRS)

USER: Department of the Navy, Navy Assessment and Control of Installation Pollutants (NACIP) Program

DEVELOPER: Adapted by the Navy from the Air Force HARM system

USE/STATUS: Currently used in the NACIP to rank sites prior to performing a complete sampling program. Part of the DOD Installation Restoration Program.

GENERAL DESCRIPTION: With three exceptions, CSRS is identical to HARM. First, while HARM employs the average of the receptors, pathways and waste characteristics subscores in determining the overall site score, CSRS uses the product of these factors (this product is multiplied by a waste management factor to give the overall site score). The receptor and pathway rating factors for both HARM and CSRS are listed in Tables B-2 and B-3. Second, CSRS evaluates containment slightly differently from HARM: limited containment is assigned a value of 0.80 in CSRS rather than 0.95 as in HARM. Finally, the two system evaluate waste characteristics very differently. HARM employs a matrix approach while CSRS evaluates waste characteristics based on the factors listed in Table B-5. Each factor is evaluated on a scale of 0 to 3. This evaluation is then multiplied by a factor-specific multiplier to form a factor score. The factor scores are then cross-multiplied, as indicated, and the results summed. This sum is then added to a physical state factor score and normalized to a scale of 0 to 1, to form the waste characteristics score.

SIMILARITIES TO HRS: The principal area of similarity between the CSRS and the HRS is in the common factors that both employ. For waste characteristics,

TABLE B-5

ILLUSTRATION OF WASTE CHARACTERISTICS SCORING METHOD

Rating Factor	Factor Rating (0 to 3)	Multiplier	Factor Score
Waste Quantity (Q)	3	1	3
Acute Toxicity (AT)	3	8	24
Chronic Toxicity (CT)	3	8	24
Persistence (P)	3	6	18
Flammability (F)	0	4	0
Reactivity (R)	0	4	0
Incompatability (I)	0	5	0
Corrosiveness (C)	0	3	0
Solubility (S)	0	5	0
Bioaccumulation (B)	3	6	18
Physical State (PS)	2	3	6
Years site was in use (t)	3	1	3
Years since site was closed (t')	3	1	3

Scoring Factor	Score	Maximum Score
AT x Q	72	72
CT x Q	72	72
C x Q	0	27
F x Q	0	36
R x Q	0	36
S x Q	0	45
P x Q x t	162	162
B x (t + t')	108	108
I x Q	0	45
Subtotal	414	603
Physical State Weighted Factors	6	9
Total	420	612

Waste Characteristics Subscore 420/612 = 0.686

SIMILARITIES TO HRS: (Concluded)

these common factors include physical state, toxicity, waste quantity, persistence, reactivity, and incompatibility. For site characteristics (pathways) and receptors (targets), the common factors are those already identified in the HARM system. For site characteristics, these include depth to aquifer/ground water, net precipitation, soil permeability and distance to nearest surface water. For targets (or receptors), these include ground water use, distance to nearest well, land use, population served by surface water or ground water, and critical environments.

DIFFERENCES FROM HRS:

The CSRS and the HRS have a number of major differences. First, their overall structures are different. In the HRS, each pathway is treated separately; in the CSRS the pathways are combined in one scoring category (pathways). Further, the CSRS does not consider the air pathway. Also, containment is treated as a single factor not a pathway specific factor. Second, the scores are combined in different fashions in the two systems. In the CSRS, the subscores are multiplied to form the site score while the HRS site score is the root mean square of the pathway scores. Third, the CSRS includes a number of factors in the ranking that the HRS does not, e.g., waste flammability, corrosiveness, bioaccumulation potential, years site was in use and years since site was closed (time factors). Finally, in the CSRS the waste characteristics score is a complex combination of the waste characteristics factors scores (e.g., the toxicity score is multiplied by the quantity score in the course of calculating the overall waste characteristics score).

There are numerous additional differences between the CSRS and the HRS, even in the areas in which they are similar. In the CSRS, acute toxicity and chronic toxicity

DIFFERENCES FROM HRS: (Concluded)

are assessed separately using Sax and NFPA; in the HRS one toxicity factor is employed. For both ground and surface water, the HRS considers just the population served by water systems as a target category while the CSRS considers both the population served and total population (residential and working) within 1,000 feet of the site. Other examples of these subtle differences exist between the systems.

CONCLUSIONS:

The concepts embedded in the following CSRS factors should be examined further (the factors themselves are generally not adequately defined for HRS purposes):

- Potential for flooding
- Surface soil permeability
- Bioaccumulation potential
- Time factors

Several other CSRS waste characteristics factors not included in the HRS were considered during the development of the HRS (e.g., solubility) but were not included in the HRS at that time because other factors were judged to be more important or because of problems with data availability and/or factor definition (47 FR 10975, March 12, 1982). Those factors not included because of the latter reasons should also be re-examined.

REFERENCES:

Luecker, Elizabeth B., "Navy Assessment and Control of Installation Pollutant (NACIP) Confirmation Study Ranking Model," Proceedings of the Twelfth Annual Environmental Systems Symposium, held on May 20-21, 1982 at Langley Air Force Base, Langley, VA, American Defense Preparedness Association, Arlington, VA, 1982.

Luecker, Elizabeth, NEESA, Port Hueneme, California, personal communication to Stuart Haus, The MITRE Corporation, April 11, 1985.

B.3 State Waste Site Ranking Systems

This section contains summaries for systems developed or used by eight states, primarily to supplement the use of the HRS in determining State priorities in addressing sites. The systems examined are as follows:

- California
- Connecticut
- Illinois
- Massachusetts
- Michigan
- New Hampshire
- New Jersey
- New York

CALIFORNIA

SYSTEM:	Public Health Benefit/Cost Ranking System
USER:	California Department of Health Services
DEVELOPER:	California Department of Health Services
USE/STATUS:	The system is used to develop the California State Priority Ranking List which is a ranking of sites for remedial action.
GENERAL DESCRIPTION:	The system assigns a Public Health Index (PHI) to a site based on the benefits and costs of remedial action at the site. The PHI is then used to rank sites for remedial action. The PHI is calculated by dividing the total benefits of remedial action by a factor which is based on the estimated cost of remedial action. The total benefits of remedial action are calculated by summing the HRS migration, fire and explosion, and direct contact scores for the site.
SIMILARITIES TO HRS:	Except for the remedial action cost factor, the system is identical to the HRS.
DIFFERENCES FROM HRS:	The system differs from the HRS in that the migration, fire and explosion, and direct contact scores are summed and then divided by the cost factor.
CONCLUSION:	The Public Health Benefit/Cost Ranking System is essentially identical to the HRS and does not need to be considered any further.
REFERENCES:	Dlugosz, Edward and Alan Ingham, "The California Ranking System," <u>Proceedings of the National Conference on the Management of Uncontrolled Hazardous Waste Sites</u>, held on November 4-6, 1985 in Washington, DC, Hazardous Materials Control Research Institute, Silver Spring, MD, 1985, pp. 429-431.

CONNECTICUT

SYSTEM: Untitled

USER: Connecticut 208 Program, State of Connecticut

DEVELOPER: TRC Environmental Consultants, Inc.

USE/STATUS: Used by State of Connecticut to assign priorities to sites for further investigation.

GENERAL DESCRIPTION: The State of Connecticut evaluation system is designed to classify sites into three hazard categories: (1) those posing no hazard and at which no further action is required, (2) those at which a hazardous condition may exist and at which further investigation or monitoring is required, and (3) those posing an imminent hazard that requires action to assure health and safety. The classification process is illustrated in Figure B-2. A site is classified as posing no hazard whenever it is not possible to follow a continuous path through the diagram. A site is classified as posing an imminent hazard whenever any of the following seven conditions pertain:

- Improperly disposed liquid PCB wastes
- Asbestos that can become airborne
- Improperly disposed pesticides
- Contaminants disposed within 200 feet of a drinking water supply
- Possible fire or explosion
- Fish kills
- Discharge of hazardous materials to storm sewers or surface water

If the determination is made that a hazardous condition may exist and further investigation is required, then additional information is collected, evaluated, and a sampling program is initiated as needed. In the case of potential air contamination, a sampling program is initiated without further investigation. In the case of suspected

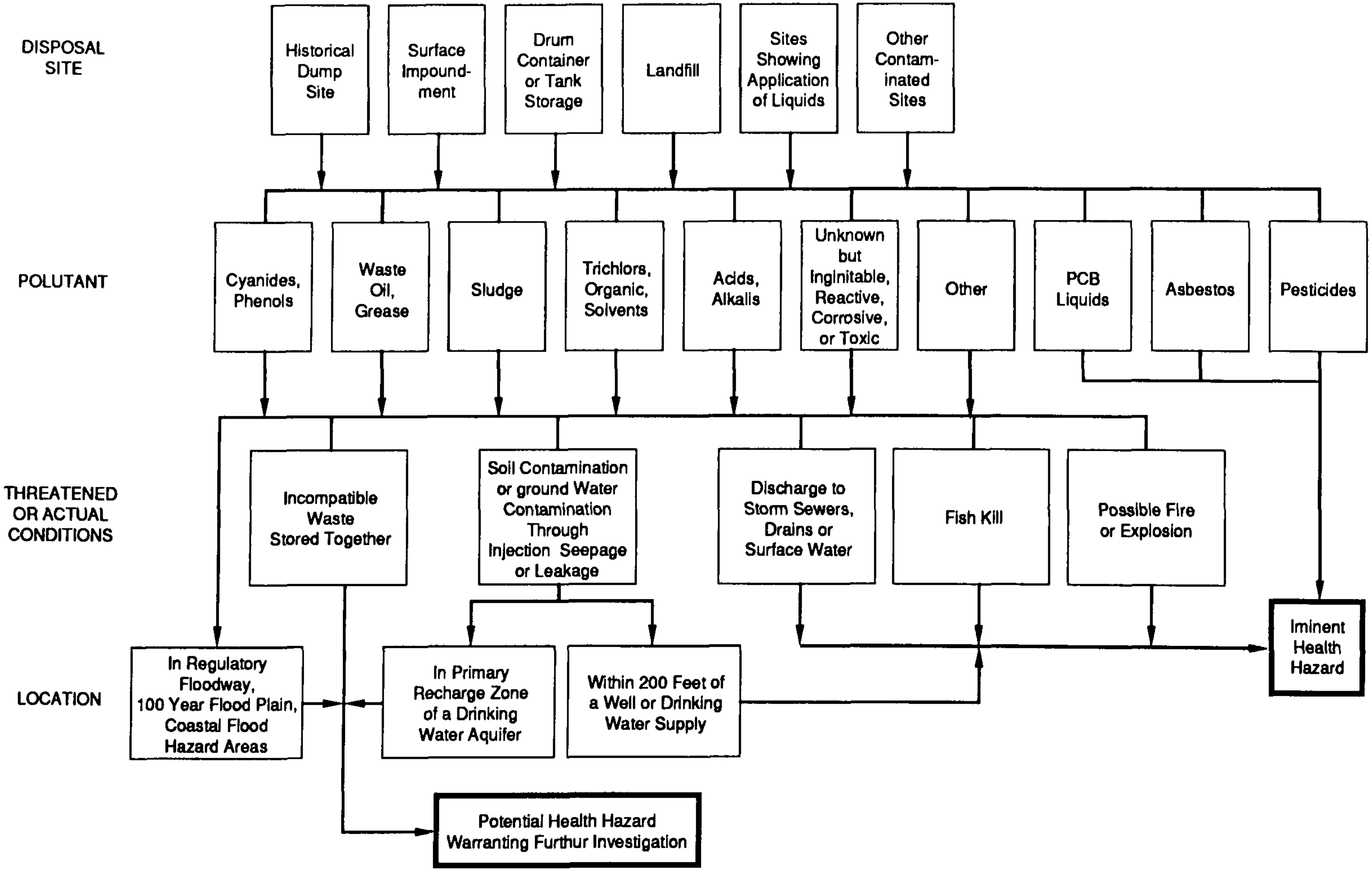


FIGURE B-2
OVERVIEW OF CONNECTICUT SCORING SYSTEM

GENERAL DESCRIPTION: (Concluded)

surface water contamination, information is obtained on the distance to the nearest waterbody and the direction of runoff before a sampling program is designed. In the case of suspected ground water contamination, an adaptation of the original LeGrand system (see Section B.4) is employed to classify the degree of hazard posed by the site and to determine the appropriate course of action. Information is collected for several characteristics of the site and used to develop factor scores for the following six factors using the line graphs in Figures B-3 (for sites underlain by loose granular material) and B-4 (for sites underlain by less than 20 feet of till or soil above the bedrock):

- Depth to water table (0 to 10 points)
- Sorption (0 to 6 points)
- Permeability (0 to 6 points)
- Gradient (0 to 7 points)
- Distance to nearby wells (0 to 7 points)
- Thickness of porous materials below disposal point (0 to 6 points)

The scores for each factor are summed to form a site score and the degree of hazard is determined as follows:

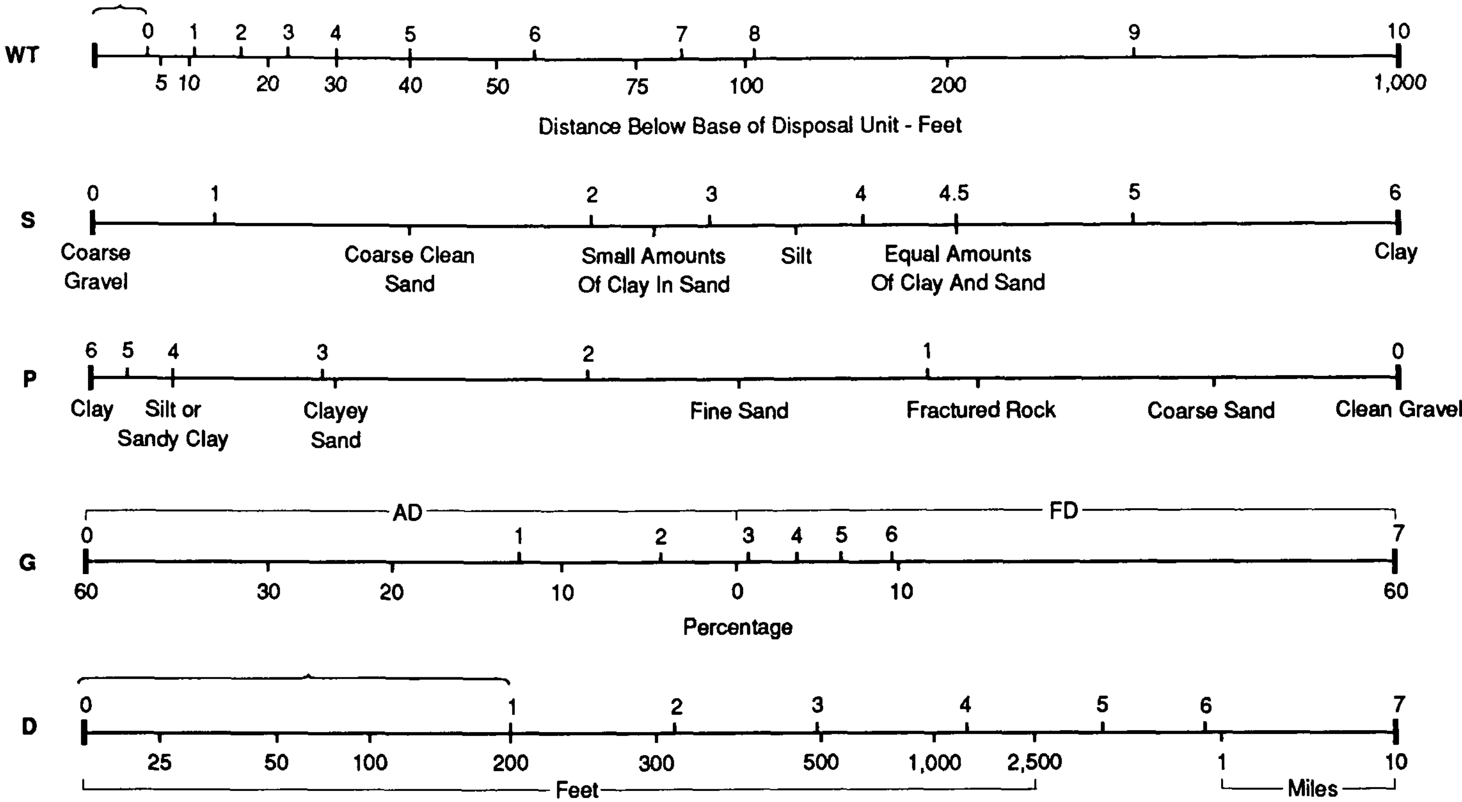
- 0 to 8: Imminent hazard
- 8 to 15: Probable or possible hazard
- Above 15: Not an imminent hazard

SIMILARITIES TO HRS:

There are few similarities between the Connecticut system and the HRS. The only important similarities are that both use the following factors, although in different fashions: depth to water table, permeability and distance to nearest well.

DIFFERENCES FROM HRS:

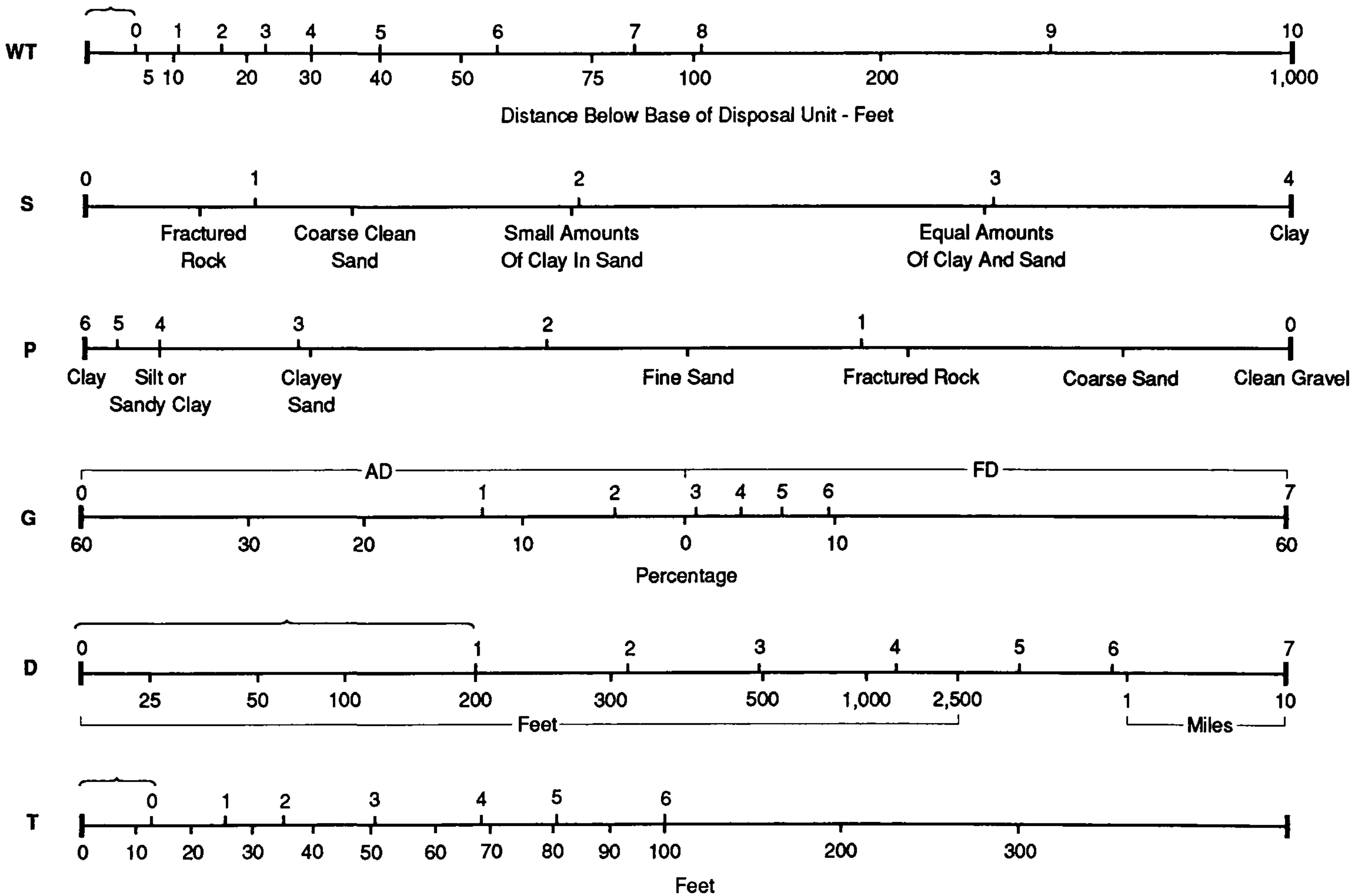
The Connecticut rating system applies only to the ground water pathway. Except for a distance to nearby wells factor, the system corresponds only to the HRS ground water route characteristics category. The



The Scales for the various factors are labeled as follows: WT, Water Table; S, Sorbtion; P, Permeability; G, Gradient; D, Distance. On all scales the point values are indicated by the upper scale; the brackets indicate unacceptable ranges for any factor, except the two brackets on the gradient scale, one labeled "AD", which is for an adverse direction of flow (toward point of water use), and one "FD" Which is for a favorable direction of flow.

Source: State of Connecticut 208 Program, 1980.

FIGURE B-3
RATING CHART FOR SITES IN LOOSE GRANULAR MATERIALS



The Scales for the various factors are labeled as follows: WT, Water Table; S, Sorbtion; P, Permeability; G, Gradient; D, Distance, and T, Thickness of porous granular materials below disposal point. On all scales the point values are indicated by the upper scale; the brackets indicate unacceptable ranges for any factor, except the two brackets on the gradient scale, one labeled "AD", which is for an adverse direction of flow (toward point of water use), and one "FD" Which is for a favorable direction of flow.

Source: State of Connecticut 208 Program, 1980.

FIGURE B-4
RATING CHART FOR TWO-MEDIA SITES

DIFFERENCES FROM HRS: (Concluded)

The Connecticut system contains three factors that do not correspond to any factors included in the HRS ground water route characteristics cateogry: sorption, gradient, and thickness of porous materials.

CONCLUSIONS:

The Connecticut system and the HRS are designed to achieve broadly similar purposes: the identification of sites that potentially pose a significant risk. Otherwise, they are not comparable, except to the extent that the original LeGrand system shares three factors in common with the HRS. The concepts embedded in the three other factors included in the Connecticut system, but not in the current HRS, should be investigated (see also the LeGrand system). The factors themselves are not adequately defined for use in the HRS.

REFERENCES:

Unites, Dennis, Mark Possidento and John Housman, "Preliminary Risk Evaluation for Suspected Hazardous Waste Disposal Sites in Connecticut," Proceedings of the National Conference on Management of Uncontrolled Hazardous Waste Sites, held on October 15-17, 1980 in Washington, DC, Hazardous Materials Control Research Institute, Silver Spring, MD, 1980, pp. 25-29.

LeGrand, Harry E., "System for Evaluation of Contamination Potential of Some Waste Disposal Sites," JAWWA, 1964, pp. 959-974.

State of Connecticut 208 Program, Hazardous Waste Site Evaluation Manual, (1076-J80-80), prepared by TRC, Environmental Consultants, Wethersfield, CT, 1980.

ILLINOIS

SYSTEM:	Rating scheme
USER:	State of Illinois, Department of Energy and Natural Resources
Developer:	State of Illinois, Department of Energy and Natural Resources
USE/STATUS:	Used by the State of Illinois as a screening tool, for regional planning, to identify and assign priorities to sites or areas for more detailed study and evaluation.
GENERAL DESCRIPTION:	The rating scheme is intended as a screening tool for regional planning. It is used to rank the relative threat to human health posed by sites via the ground water pathway. The rating scheme is composed of four factors: health risk of waste and handling mode, population at risk, proximity of waste activity to public water supply wells or potable aquifer, and aquifer susceptibility. The elements contained in these factors are listed in Table B-6. Each element is assigned a numerical value (on a scale ranging between 0 and 10, 50, 80, or 100) according to prescribed guidelines. These guidelines are different for active and abandoned sites. Total scores for the first three factor range from 0 to 100, while the score for the fourth factor ranges from 0 to 50. The four factor scores are added and divided by 3.5 to give an overall score between 0 and 100.
SIMILARITIES TO HRS:	The rating scheme is intended to evaluate ground water threats. As such, it corresponds to the HRS ground water pathway. The rating scheme and the HRS ground water pathway contain three elements that are similar in concept, but which are defined and evaluated differently. These are: waste quantity, waste hazard, population at risk, and aquifer susceptibility.

TABLE B-6

FACTORS AND ELEMENTS IN THE ILLINOIS RATING SCHEME

Factors	Elements
Health risk of waste and handling mode	Waste quantity Recorded management of waste Potential hazard of waste
Population at risk	Population at risk if within public water supply well capture zones Population at risk for sites outside public water supply well capture zones
Proximity of waste activity to public water supply	Age of hazardous waste activity if within public water supply well capture zones Density of hazardous waste activity for sites outside public water supply well capture zones
Aquifer susceptibility	Aquifer susceptibility to surface sources of pollution

Source: Gibb et al., 1983.

DIFFERENCES FROM HRS: The rating system contains two elements that do not correspond to any factors present in the HRS ground water pathway: recorded management of hazardous waste (e.g., whether the site was well operated, whether it received municipal or industrial wastes) and the age or density of hazardous waste activity relative to the proximity of the activity to public water supplies. As noted above, four other factors in the rating scheme are evaluated differently than in the HRS. Waste hazard applies only to RCRA listed wastes and is evaluated using the ranking scheme from the RCRA Risk-Cost Analysis Model. Population at risk is evaluated by determining whether a site falls within a 75-year capture zone of a public water supply well. If so, it is scored based on the population using the well; if not, it is scored based on population density. Waste quantity is based upon a different scale than in the HRS and is evaluated differently for abandoned sites and active sites. Waste susceptibility is evaluated based on the thickness and permeability of the material overlaying an aquifer.

CONCLUSIONS: The population at risk element in the rating scheme needs to be further evaluated with regard to its applicability to the HRS. The other factors are either not appropriate for inclusion in the HRS (e.g., recorded management of waste) or are not adequately defined in their present form for inclusion in the HRS (e.g., aquifer susceptibility).

REFERENCES:

Gibb, J., M. Barcelona, S. Schock, and M. Hampton, Hazardous Waste in Ogle and Winnebago Counties: Potential Risk via Groundwater Due to Past and Present Activities, Illinois Department of Energy and Natural Resources, Document No. 83/26, Springfield, IL, 1983.

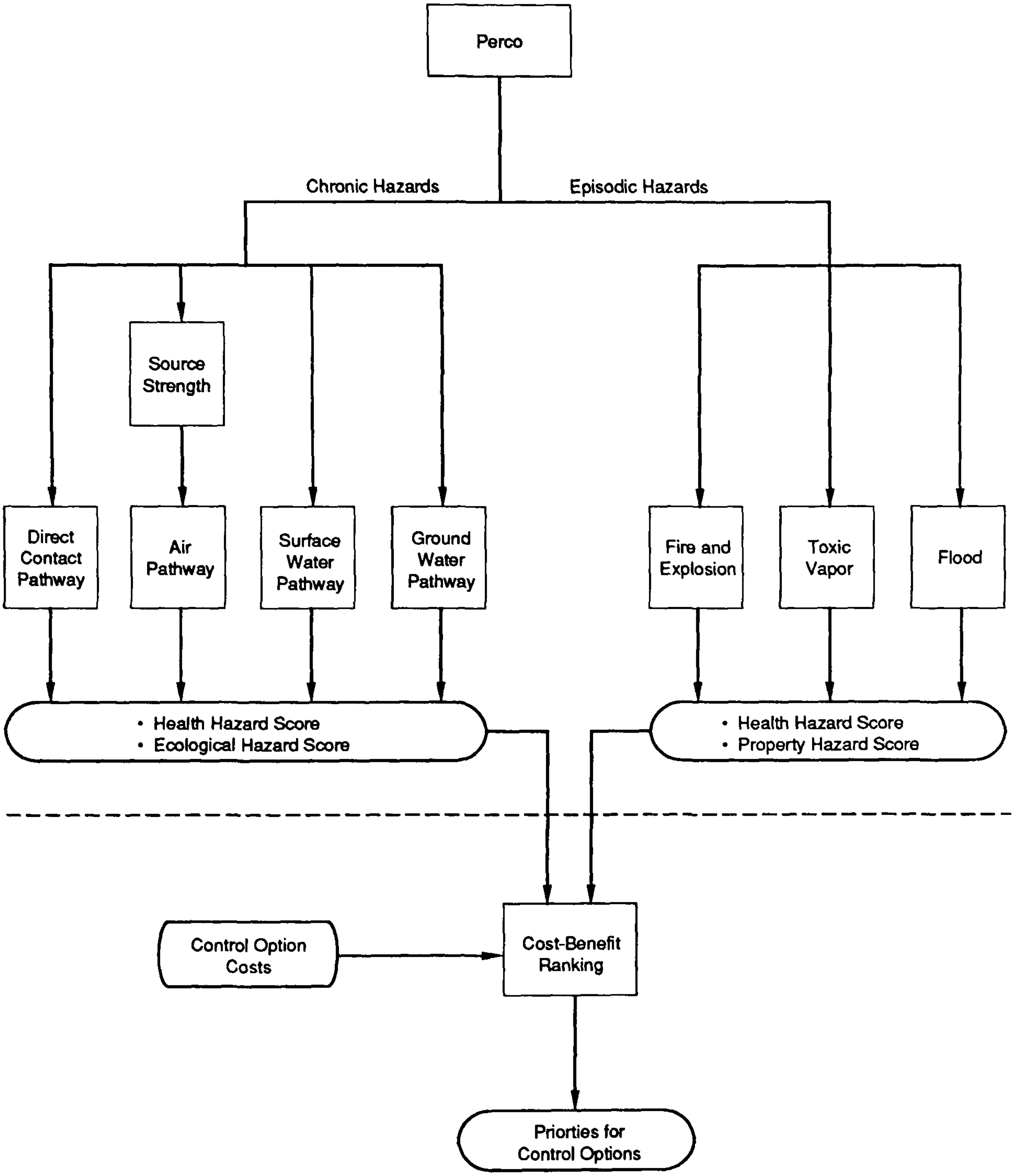
MASSACHUSETTS

SYSTEM:	Prioritization of Environmental Risks and Control Options (PERCO)
USER:	Developed for the Massachusetts Department of Environmental Quality Engineering (DEQE)
DEVELOPER:	Arthur D. Little, Inc.
USE/STATUS:	The development of PERCO has been completed by Arthur D. Little. It is now being studied by DEQE. No schedule is available for possible implementation of PERCO by DEQE.

GENERAL DESCRIPTION:

PERCO was designed by ADL with the objective of enabling DEQE to rank sites in terms of immediate and long-term environmental and human health hazards and to provide a rationale for allocation of remedial action funds. The model was designed to reflect the risks of the sites and the risk/benefit trade-offs that might result from remedial actions. The model addresses both chronic and episodic (acute) hazards. Four pathways are used for chronic hazards: air, ground water, surface water, and soil/direct contact. Three types of episodic hazards are considered: fire and explosion, toxic vapor, and floods. The overall PERCO structure is illustrated in Figure B-5.

With regard to the four chronic pathways, a human health score is calculated for each pathway, as described below, and the four human health scores are summed to determine the total health score for the site. In addition, for the surface water pathway, three optional scores (i.e., recreation, fishing, and ecological) may be calculated. For the soil/direct contact pathway, an optional land score may be calculated. These optional scores are not used in determining the total site score; rather they just provide additional information for subjective use by DEQE.



Source: Arthur D. Little, Inc., 1982.

FIGURE B-5
OVERVIEW OF PERCO SYSTEM

GENERAL DESCRIPTION: (Continued)

For the ground water and surface water pathways, the human health score is determined through the use of concentration data and human health effects benchmarks. The concentration of each hazardous constituent (based on one or more samples) is divided by a subjectively chosen, chronic human health benchmark for that constituent. This gives a severity ratio for each constituent. The severity ratio for each constituent is then summed to give the total severity ratio. This total severity ratio is then multiplied by the population served by the water body to give the human health score. The distance from the site over which the surface water or ground water population is counted is subjectively determined by the person rating the site. If concentration data (i.e., at least one sample) are not available for a site, then similar sites to the site being scored are identified subjectively or in the case of the surface water pathway through the use of optional guidelines. The concentration data from these similar sites are then used in the above procedure to determine a human health score for the site being rated.

Two of the three optional surface water scores (recreation and fishing) are calculated in a similar manner. The total contaminant severity ratio is multiplied by either the annual person-hours of recreation for the water body (recreation score) or the pounds of fish caught and eaten from the water body multiplied by a bioconcentration factor (fishing score). The ecological score is the maximum ratio of the contaminant concentrations divided by a subjectively chosen ecological toxicity benchmark.

For the soil/direct contact pathway, the human health score is determined by dividing

GENERAL DESCRIPTION: (Continued)

the acres of crops grown in contaminated soil off the site by a subjectively chosen crop concentration factor (CCF). (The CCF is meant to relate the contamination of irrigated crops by water to resulting human health risks and damages. No guidance is provided for determining the CCF. The HRS factor of 1.5 persons per irrigated acre is recommended as a default value.) The above ratio is summed for each crop, and the sum is the soil/direct contact human health score.

The optional land score for the soil/direct contact pathway is calculated by first determining the annual person-hours of people present on the contaminated soil. This is the usage rate. The usage rate is divided by a subjectively chosen acute human health toxicity benchmark. This ratio is the land score. The land score is summed for all contaminated soil to give the total land score.

For the air pathway, the human health score is obtained by first determining a set of concentric concentration rings around the site. The population within each ring is determined and multiplied by a weight for that ring. The weighted population for each ring is then summed to give the human health score for the air pathway. The radius of each ring is determined through a complex procedure involving the use of simplified air dispersion equations and subjectively chosen human health effects benchmarks. One or more air samples from downwind of the site is required for the calculation. If such monitoring data are not available, then similar sites to the site being rated are identified either subjectively or through the use of optional guidelines. The concentration data from these similar sites are then used in the above procedure.

GENERAL DESCRIPTION: (Concluded)

In addition to the four chronic pathway scores, three episodic (acute) hazard scores are determined. These episodic scores are not used in calculating the total site score; rather they provide additional information for subjective use by DEQE. Two of the episodic scores (toxic vapors and fire and explosion) are determined in a manner that is generally similar in concept to the air pathway health score. The flooding score is calculated as the product of a flooding potential factor, a waste quantity factor, and a toxicity/persistence factor.

SIMILARITIES TO HRS:

The principal similarity between the HRS and PERCO is that both address the ground water, surface water, air, direct contact, and fire and explosion pathways. The methods used in each for addressing these pathways are very different, however. The only similarity is that both consider the population-at-risk.

DIFFERENCES FROM HRS:

PERCO and the HRS are very different systems. PERCO requires that concentration data be used in rating a site. Just one sample is considered sufficient for rating a site. If data are not available, PERCO attempts to identify similar sites to the site being ranked and uses data from those similar sites in ranking the site. Thus PERCO implicitly assumes that a fairly comprehensive set of ambient measurements for hazardous waste sites exists. The HRS, in contrast, uses concentration data primarily to determine if an observed release has occurred. If there is no observed release, the HRS uses surrogate (potential for release) measures. Another critical difference between the two systems is that many of the factors used in PERCO are subjectively determined by the person rating the site. These include the health effects benchmarks and the surface water and ground water target distance limits. In the

DIFFERENCES FROM HRS: (Concluded)

HRS most factors are specified in advance to ensure consistent and uniform rating of sites. Another difference is that PERCO addresses options for remedial action and subjectively assesses their risk/benefit trade-offs. This is not done in the HRS.

CONCLUSIONS:

Four concepts used in PERCO warrant further evaluation. One is the use of health effects benchmarks as part of any concentration based factor. The second is the use of data from similar sites rather than using potential for release factors in rating a site. The third is the use of air dispersion equations to specify distance rings for rating the target population in the air pathway. (The HRS currently uses distance rings, but they are specified in advance and do not vary from site to site.) The last is the use of flooding factor. None of the four concepts are defined well enough in PERCO for direct use in the HRS.

REFERENCES:

Arthur D. Little, Inc., PERCO: A Model for Prioritization of Environmental Risks and Control Options at Hazardous Waste Sites, Arthur D. Little, Inc., Cambridge, MA, September 12, 1983.

Bois, Robert, Massachusetts Department of Environmental Quality Engineering, personal communication to Carol Burger, The MITRE Corporation, September 18, 1986.

MICHIGAN

SYSTEM:	Site Assessment System (SAS)
USER:	State of Michigan, Department of Natural Resources
DEVELOPER:	State of Michigan: Department of Natural Resources, Department of Agriculture, Legislative Bureau, Department of Health, and Toxic Substance Control Commission
USE/STATUS:	Currently used by the State of Michigan to assess and prioritize sites, in terms of relative risk, for further investigation and remedial action.

GENERAL DESCRIPTION:

SAS is a multi-pathway ranking system designed to reflect the relative risk posed by sites to public health and environmental resources. The system is illustrated in Tables B-7 and B-8. Five exposure pathways are reflected in SAS: ground water, surface water, air, direct contact, and fire and explosion. Each pathway is evaluated independently, and a site subscore calculated as the square root of the sum of the squares of the pathway scores. This score is then added to a chemical hazard score to form the overall site score.

Each pathway score is the sum of a potential exposure score and an existing exposure score. In turn, the potential exposure score is the product of a release potential score multiplied by the sum of environmental exposure, and targets scores. This calculation procedure is illustrated in Table B-7. The factors addressed in evaluating these scores are listed in Table B-8.

The chemical hazard score is evaluated, independent of pathway, using the complex approach illustrated in Figure B-6. This approach considers diverse factors including

TABLE B-7
MICHIGAN SITE ASSESSMENT SYSTEM SCORE SHEET

Category \ Route		Ground Water: Rating Factor	Ground Water: Range of Scores	Ground Water: Site Score	Surface water: Rating Factor	Surface water: Range of Scores	Surface water: Site Score	Air: Rating Factor	Air: Range of Scores	Air: Site Score	Direct Contact: Rating Factor	Direct Contact: Range of Scores	Direct Contact: Site Score	Fire and Explosion: Rating Factor	Fire and Explosion: Range of Scores	Fire and Explosion: Site Score
Potential Exposure	Release Potential (RP)	Release Potential	0-2		Release Potential	0-2		Release Potential	0-2		Release Potential	0-2		Release Potential	0-2	
	Environmental Exposure (EnE)	Un-saturated Zone	0-100		Distance To Surface Water	0-40		Mobility	0-70		Access-ability	0-80		Ignition Source	0-50	
					Site Slope	0-40										
					Flood Potential	0-20		Site Activity	0-30		Atract-iveness	0-20		Waste Separation	0-50	
	Targets (T)	Population At Risk	0-100		Population At Risk	0-100		Population	0-100		Population	0-100		Population	0-100	
					Drinking Water Population	0-40										
					Wetlands	0-10										
		Saturated Zone	0-60		Cold Water Fish	0-15								Wetlands	0-10	
					Warm Water Fish	0-10										
Potential Exposure (PE) Score - (EnE+T) x RP			0-520			0-530			0-400			0-400			0-420	
Existing Exposure	Existing Exposure (E&E)	Existing Exposure	0-250		Existing Exposure	0-250		Existing Exposure	0-250							
Route Score PE + E&E			0-770			0-780			0-650			0-400			0-420	

Subscore (SS)	$[GW^2 + SW^2 + Air^2 + DC^2 + FE^2]$	$\left[[770]^2 + [780]^2 + [650]^2 + [400]^2 + [420]^2\right]$ 1/2	0-1,400	
Chemical Hazard	Chemical Hazard (CH)			
		Site Score CH + SS	0-2,000	

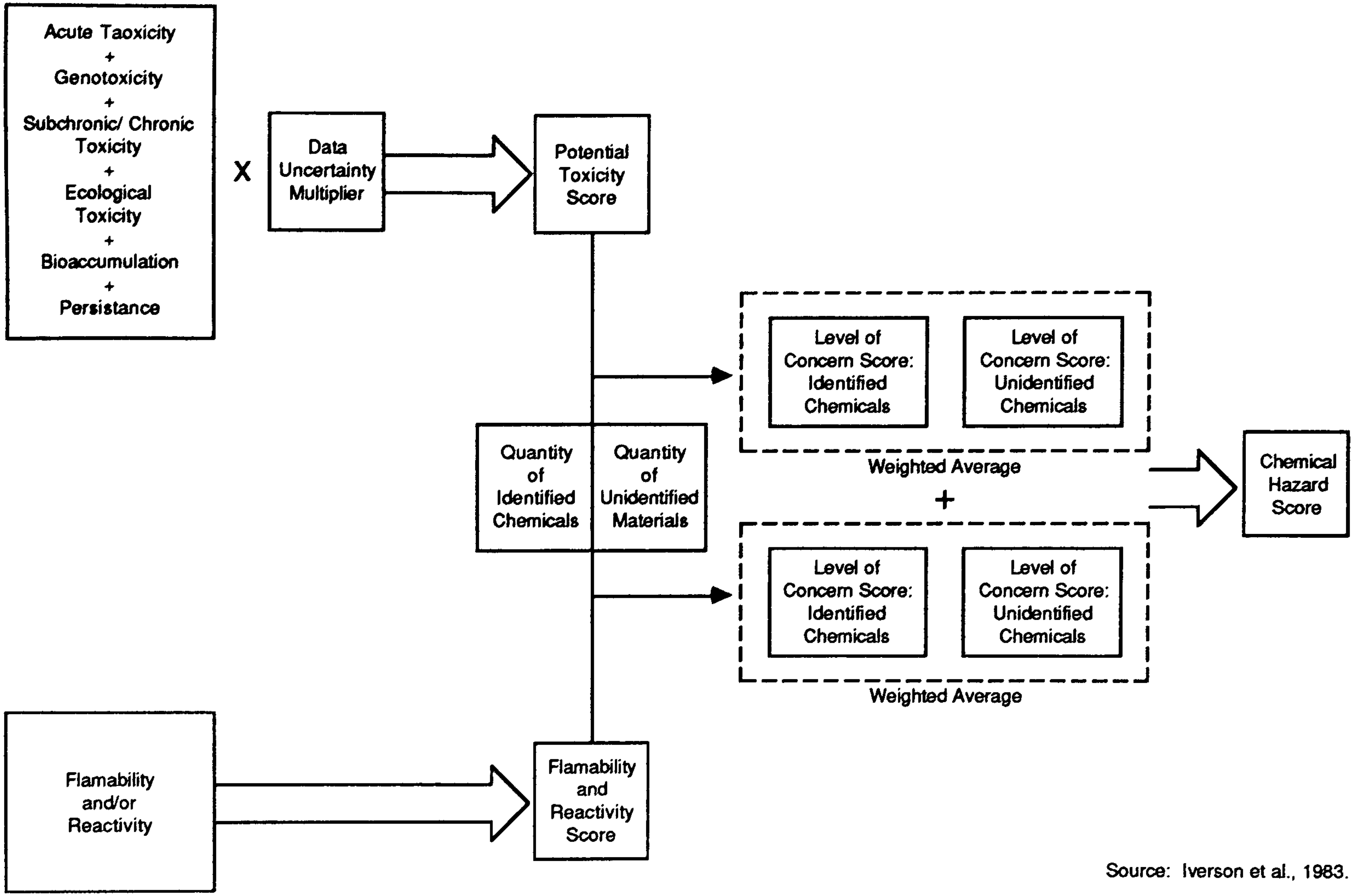
Source: Iverson et al., 1983.

TABLE B-8
SITE ASSESSMENT SYSTEM RATING FACTORS

Category \ Route		Ground Water	Surface Water	Air	Direct Contact	Fire and Explosion
Release Potential		Physical state Containment effectiveness	Physical state Containment effectiveness	Physical state Containment effectiveness	Physical state Containment effectiveness	Physical state Containment effectiveness
Environmental Exposure		Unsaturated zone	Site slope Flood potential Distance to surface water	Mobility Site activity	Accessibility Attractiveness	Ignition source Waste segregation
Targets	Population at Risk	Population within target area Population served by well field within 1/2 mile of site	1/2 the population within the target area Drinking water supply population	Population within target area	1/2 the population within the target area	Population within target area
	Resource Value	Saturated zone	Fisheries designation Wetlands Drinking water	Non-applicable	Non-applicable	Wetlands
Existing Exposure		Exposure over background levels Population exposed	Exposure over background levels Population exposed Fish advisory	Exposure over background levels Population exposed Odors	Non-applicable	Non-applicable

Chemical Hazard	Mammalian toxicity Aquatic toxicity	Bioaccumulation Persistance	Flammability Reactivity	Chemical quantity

Source: Iverson et al., 1983.



Source: Iverson et al., 1983.

FIGURE B-6
SITE ASSESSMENT SYSTEM CHEMICAL HAZARD SCORING PROCESS

GENERAL DESCRIPTION: (Concluded)

toxicity (acute, subchronic, chronic, ecological, and genotoxicity), bioaccumulation potential, persistence, flammability, reactivity, and data uncertainty.

SIMILARITIES TO HRS:

There are several similarities between the HRS and the SAS, as seen in Tables B-7 and B-8. Each employs the same five pathways. Each addresses potential and observed release, similar targets and waste characteristics. Additionally, many of the same factors are employed in evaluating the categories. Both systems employ the root-mean-square of the weighted sum of the pathway scores to form the site score (or subscore).

DIFFERENCES FROM HRS:

There are several significant differences between the two systems (see Tables B-7 and B-8). First, SAS addresses potential and existing exposure separately, and adds the scores for both to form the route score.

Second, the waste characteristics/chemical hazards portions of the two systems, while serving similar purposes, are evaluated very differently. In the HRS, the degree of hazard posed by the wastes is evaluated for each pathway in terms of the Sax toxicity score together with other factors such as quantity and persistence. In contrast, SAS employs the approach discussed above. Also, chemical hazard in SAS is treated independently of pathway (in contrast to the HRS approach).

Third, the two systems are combinatorially very different. For example, in the SAS ground water pathway, a score for permeability and depth to the aquifer of concern (unsaturated zone factor score) are added to the targets score, the sum then multiplied by the release potential score to form the potential exposure score. In the

DIFFERENCES FROM HRS: (Concluded)

HRS, permeability, depth to aquifer and other factor values are summed and then multiplied by a targets value to form a similar score. Further, the pathway score is the sum of the exposure subscore and the chemical hazard score in SAS, while in the HRS, the waste characteristics score (which includes toxicity related factors) is multiplied by the release category and targets values to form the overall score. Also, all five pathways are included in SAS in evaluating the site score. In contrast, the direct contact and fire and explosion pathways are not included in the HRS site migration score.

Finally, in many cases, the procedures used to evaluate the common factors are different in the two systems. For example, in the SAS ground water pathway, permeability and thickness of the unsaturated zone are evaluated in a matrix, while in the HRS, they are evaluated independently and their factor values added.

CONCLUSIONS:

SAS is a complex ranking system, sharing some characteristics with the HRS, while also differing strongly from the HRS in other respects. It considers many of the same factors as the HRS although the scoring methods are usually different. The complex method used to evaluate chemical hazard should be evaluated in detail for possible adaptation for use in the HRS.

REFERENCES:

Iverson, Christine et al., Site Assessment System (SAS) for the Michigan Priority Ranking System under the Michigan Environmental Response Act (Act 307, P.A. 1982), Michigan Department of Natural Resources, Lansing, MI, November 1983.

Michigan Department of Natural Resources, 1984 Review Report Michigan Site Assessment System, Michigan Department of Natural Resources, September 1984.

REFERENCES:
(Concluded)

Michigan Department of Natural Resources, Appendix C: Guidance to SAS Model Application, Michigan Department of Natural Resources, July 1985.

Roycroft, Dianne, Michigan Department of Natural Resources, Groundwater Quality Division, personal communication to Thomas F. Wolfinger, The MITRE Corporation, August 1985.

NEW HAMPSHIRE

SYSTEM: Untitled

USER: New Hampshire Department of Health and Welfare

DEVELOPER: New Hampshire Department of Health and Welfare

USE/STATUS: Used by New Hampshire to rank sites for further assessment and remedial action.

GENERAL DESCRIPTION: New Hampshire uses its system to rank hazardous waste disposal sites in three categories; high, medium and low priority. The indicator of hazard is potential for carcinogenic effects. By default, all NPL sites are assigned a high priority. Thus, the focus of the system is on non-NPL sites. The system is simple; site scores are the sum of a carcinogenic potential score and an exposure potential as shown. Carcinogenic potential is scored as follows:

- Human postive: 3
- Animal positive: 2
- Nonsuspect: 1

Presumably, the score is based on the maximum carcinogenic potential of all the substances at the site.

Exposure potential is scored as follows:

- Direct exposure: 3
- Potential exposure: 2
- Unlikely exposure: 1

SIMILARITIES TO HRS: The only important similarity between the two systems is that the New Hampshire system assigns a high priority to NPL sites and hence to sites with an HRS score exceeding 28.50.

NEW HAMPSHIRE (Concluded)

DIFFERENCES FROM HRS: The only important difference between the two systems is the method used by New Hampshire to score carcinogenic potential.

CONCLUSIONS: The method for scoring carcinogenic potential should be examined when the HRS methods for scoring toxicity are examined.

REFERENCES:

Dupee, Brook S., Environmental Health Risk Assessment Unit, Memorandum to Brian C. Strohm, Assistant Director, Division of Public Health Services, New Hampshire Department of Health and Welfare, May 18, 1984.

Dupee, Brook S., Environmental Risk Assessment Unit, New Hampshire Department of Health and Welfare, personal communication to Stephen Lubore, The MITRE Corporation, March 8, 1985.

Dupee, Brook S., Environmental Risk Assessment Unit, New Hampshire Department of Health and Welfare, personal communication to Thomas F. Wolfinger, The MITRE Corporation, September 13, 1985.

NEW JERSEY

SYSTEM: Severity Index

USER: State of New Jersey, Department of Environmental Protection (DEP), Division of Hazardous Waste Management

DEVELOPER: Unknown

USE/STATUS: Used by New Jersey DEP to prioritize sites for site inspection.

GENERAL DESCRIPTION: The Severity Index is used by the New Jersey DEP to prioritize sites for site inspections (SI) based on the data obtained during a preliminary assessment (PA). The Severity Index calculates a total site score as the product of a waste characteristics score and an exposure potential score, divided by 100 to normalize the final score.

In determining the waste characteristics score, the system employs the HRS toxicity/persistence, waste quantity, and containment factors and associated evaluation tables. The waste characteristics score is calculated as the sum of the toxicity/persistence score and the waste quantity score all multiplied by the containment score.

The exposure potential score is the product of a population density/sensitive environment score multiplied by the sum of six exposure medium scores. The six exposure media are:

- Ground water
- Surface water
- Air
- Soil
- Fire/explosion
- Direct contact

The population density/sensitive environment scoring approach is unique to the Severity

GENERAL DESCRIPTION: (Concluded)

Index. The six exposure medium scores are each calculated as the product of a basic score and an observed score. If contamination is observed in the medium under consideration, then the observed score is set equal to 2; otherwise it is set equal to 1. The basic scores for the ground water and surface water medium are similar to the HRS ground water and surface water use factors. The remaining four basic scores are based on assessments of the potential for contamination of air or soil, for direct contact of hazardous substances by humans, or for fire and explosion. If such a potential is deemed to exist for any of the four exposure media, a basic score of three is assigned to that exposure medium; otherwise, a basic score of zero is assigned to that exposure medium.

SIMILARITIES TO HRS:

Most of the factors in the Severity Index are identical to, or very similar to, HRS factors. These factors and their evaluation methods are the only similarities between the two systems.

DIFFERENCES FROM HRS:

The major difference between the two systems lie in the four exposure medium scores used in the Severity Index, the algorithms used to calculate the overall site scores (as discussed above), and the many factors included in the HRS that are not reflected in the Severity Index (e.g., the ground water route characteristics factors). The four exposure medium scores are apparently assessed subjectively. If a potential for exposure exists in the opinion of the analyst, a maximum score of 3 is assigned. If not, a score of 0 is assigned.

CONCLUSION:

The Severity Index is derived from the HRS. No further analysis is warranted.

REFERENCES:

Kenneth J. Kloo, New Jersey Department of Environmental Protection, letter and attachments to Wayne Praskins, U.S. Environmental Protection Agency, Washington, DC, July 30, 1986.

NEW YORK

SYSTEM: Human Exposure Potential Ranking Model (HEPRM)

USER: State of New York, Department of Health, Bureau of Toxic Substance Assessment

DEVELOPER: Life Systems, Inc.

USE/STATUS: Under development for the New York State Department of Health to prioritize sites for further investigative and remedial actions.

GENERAL DESCRIPTION: HEPRM is designed to rank sites based on their potential for impacting human health. Scores are first developed within the system for 40 potential human exposure pathways (e.g., ingestion of surface water). The human exposure pathways are grouped into four media (i.e., air, soil, ground water, surface water). A score is determined for each medium by summing the appropriate pathway scores. The overall site score is determined by summing the scores for each medium. Table B-9 lists the human exposure pathways within each medium.

Each human exposure pathway score is calculated as the product of four factors: a chemical factor, a target factor, a probability of release factor, and a weighting factor. Each of these factors is determined based on other factors, as discussed below. These other factors vary according to the exposure pathway being scored.

There are seven chemical factor scores, only one of which is used per exposure pathway. Each of the seven chemical factor scores is calculated as the product of a toxicity score and a migration potential score. Three route-specific toxicity scores (i.e., ingestion, inhalation, and dermal) and a general toxicity score are determined for contaminants based on the Sax rating scheme used in the HRS. Four categories of

TABLE B-9

HEPRM EXPOSURE PATHWAYS

Air

- Inhalation of air vapor (on-site)
- Inhalation of air vapor (off-site)
- Inhalation of particulates (on-site)
- Inhalation of particulates (off-site)
- Inhalation of soil vapor (basement)

Soil

- Ingestion of soil (on-site)
- Dermal contact with soil (on-site)
- Ingestion of plants (on-site)
- Ingestion of airborne soil (off-site)
- Dermal contact with airborne soil (off-site)
- Ingestion of plants (airborne) (off-site)
- Ingestion of waterborne soil (off-site)
- Dermal contact with waterborne soil (off-site)
- Ingestion of plants (waterborne) (off-site)

Ground Water

General:

- Ingestion of ground water (water supply)
- Inhalation of ground water (water supply)
- Dermal contact with ground water (water supply)
- Inhalation of ground water vapor (basement)
- Dermal contact with ground water (basement)
- Dermal contact with seepage
- Ingestion of plants (irrigation)

Surface Water Recharged by Contaminated Ground Water:

- Ingestion of surface water (water supply)
- Dermal contact with surface water (water supply)
- Inhalation of vapors from surface water (water supply)
- Ingestion of surface water (recreation)
- Dermal contact with surface water (recreation)
- Ingestion of plants (irrigation)
- Ingestion of aquatic biota

TABLE B-9 (Concluded)

Surface Water

General:

- Ingestion of surface water (water supply)
- Dermal contact with surface water (water supply)
- Ingestion of surface water (recreation)
- Dermal contact with surface water (recreation)
- Ingestion of aquatic biota
- Ingestion of plants (irrigation)

Surface Water Receiving Runoff from Lagoon Overflow:

- Ingestion of surface water (water supply)
- Dermal contact with surface water (water supply)
- Inhalation of vapors from surface water (water supply)
- Ingestion of surface water (recreation)
- Dermal contact with surface water (recreation)

GENERAL DESCRIPTION: (Continued)

migration scores (i.e., soil contact, soil vapor, ground water vapor, and ground water contact) are calculated and are generally based on vapor pressure and water solubility characteristics of the contaminants. The three toxicity routes and the four migration categories are used to define the seven chemical factor scores (e.g., chemical factor score for soil contact-ingestion). The score for each chemical factor is based on the one contaminant with the highest score for that chemical factor.

There are seven probability scores, only one of which is used per exposure pathway. The seven probability scores are each calculated differently; however, each provides for assessing the probability based on either documented evidence of release or potential for release (or potential for contact, as applicable), as does the HRS. Table B-10 lists the factors evaluated in each "potential" probability calculation. Many of the factors are identical or nearly identical to factors in the HRS, as indicated in the table.

There are 18 target scores, only one of which is used per exposure pathway. The 18 target scores share a common, basic methodology.

In each, the population potentially affected is estimated in up to four distance classes. The classes are based on concentric rings at specified distances from the site. For example, the four classes used to estimate the ground water supply target score are (1) less than 160 meters, (2) 160 to 1,000 meters, (3) 1,001 to 4,000 meters, and (4) greater than 4,000 meters. The potentially affected population is calculated for each class and evaluated using a population scoring table. The final target score is the normalized sum of the products of the population scores for each distance class and a distance class score. Several of the target scoring

TABLE B-10

HEPRM PROBABILITY FACTORS

Category	Factors
On-Site Contact	Accessibility Containment Adjacent Population
Ground Water Transport	Aquifer Proximity* Net Precipitation* Permeability* Containment* Leaching Potential**
Air Vapor Transport	Containment Reactivity/Incompatability* Evaporation Potential***
Air Particulate Transport	Precipitation (Percent Dry Days) Containment Site Area Disturbance
Surface Water Transport	Containment* Rainfall* Site Area Disturbance Site Slope/Terrain*
Soil Vapor Transport	Permeability* Evaporation Potential*** Containment* Landfill Type Depth to Waste
On-Site Plant Ingestion	Not available

*Factor identical or nearly identical to HRS factor.
**Based on vapor pressure and water solubility of contaminants of concern.
***Based on vapor pressure of contaminants of concern.

GENERAL DESCRIPTION: (Concluded)

procedures employ variations on this approach to reflect specific additional considerations. For example, the on-site contact target scores employ only one class since the targets are all on-site.

In addition to the chemical, probability and target scores, HEPRM employs 40 weighting factors reflecting the relative importance of each human exposure pathway in determining overall human health risk. These weighting factors were developed based on the product of an exposure coefficient and the estimated maximum daily intake of contaminant resulting from a concentration of 1 ppm of contaminant in the appropriate media. The exposure coefficient for each pathway was based on a "reasonable worst case" estimate of exposure frequency, duration, and magnitude as well as other relevant factors.

As stated above, the 40 exposure pathway scores are calculated as the product of the appropriate chemical factor scores, probability scores, target scores, and weights.

SIMILARITIES TO HRS:

There are two important areas of similarity between HEPRM and the HRS. Both address common routes for human exposure and associated potential human health impact, for example ingestion of contaminated ground water. Also, as indicated above, the two systems share many common factors and several HEPRM factors are based on HRS factors (e.g., containment and net precipitation in assessing the probability of ground water transport).

DIFFERENCES FROM HRS:

Despite the similarities between HEPRM and the HRS, there are a large number of differences between the two systems. The more important differences are differences in basic philosophy, differences in the exposure pathways, differences in the

DIFFERENCES FROM HRS: (Continued)

calculation procedures, and differences in the applicability of the systems. There are also minor differences in the approaches used to calculate common factors (e.g., for many factors, the minimum score in HEPRM is 0.1 rather than 0 as is used in the HRS).

As discussed above, HEPRM is an exposure pathway system while the HRS is a contaminant migration pathway system. Thus, HEPRM delineates a large number of exposure pathways explicitly, while the HRS delineates three basic contaminant migration pathways explicitly and implicitly reflects several exposure pathways simultaneously within each migration pathway. Nonetheless, there are several exposure pathways delineated in HEPRM that are not reflected in the HRS, such as soil ingestion, contaminated plant and aquatic biota ingestion, and dermal contact with seepage.

In addition, the calculation algorithms used are very different even when nearly identical factors are employed. HEPRM is fundamentally multiplicative in determining the exposure pathway scores. For example, the probability of ground water transport score is the product of the scores for aquifer proximity, net precipitation, permeability, containment and leaching potential. The corresponding calculation in the HRS uses the sum of the factor values for the first three factors (and a fourth factor, physical state, not included in HEPRM) all multiplied by the containment factor value.

Further, the overall site score in HEPRM is the sum of the exposure pathway scores while the site score in the HRS is the root mean square of the migration pathway scores.

The final significant difference between the two systems is that HEPRM addresses human health risks only while the HRS addresses human health and environmental risks

DIFFERENCES FROM HRS: (Concluded)

simultaneously. A separate system to assess environmental risks (Biothreat Ranking Model) is currently in the early stages of development.

CONCLUSIONS:

There are several characteristics of HEPRM that should be investigated further for possible adaptation into the HRS. These characteristics are all related to the exposure pathways not currently reflected in the HRS, such as ingestion of soil and ingestion of aquatic biota.

REFERENCES:

Life Systems Inc., Briefing on Human Exposure Potential Ranking Model (HEPRM), Workshop on Prioritization Techniques/ Ranking Models, Oak Ridge Associated Universities, July 15, 1986.

B.4 Other Waste Site Ranking Systems

This section contains summaries of ten additional systems developed to rank sites for various purposes. The systems are as follows:

- Arthur D. Little
- Rating and Risk Assessment Methodology (Dames and Moore)
- Hagerty, Pavoni, and Herr System
- JRB Associates Model
- LeGrand System
- Monroe County Methodology
- Olivieri and Eisenberg Assessment Methodology
- Phillips, Nathwani, and Mooij Matrix
- Rating Methodology Model
- Objective Calculation Procedure

ARTHUR D. LITTLE, INC.

SYSTEM:	Untitled
USER:	None has been identified
DEVELOPER:	Arthur D. Little, Inc
USE/STATUS:	Prepared for the Chemical Manufacturers Association as an alternative approach to the HRS.

GENERAL DESCRIPTION:

The Arthur D. Little, Inc. (ADL) system was developed as an alternative to the HRS. Similar to the HRS, it is designed to rank sites based on the relative risk they pose to public health. The ADL system addresses three pathways: ground water, surface water and air, each evaluated on a scale of 0 to 100. The site score is the sum of the pathway values, and ranges between 0 and 300. Three factor categories are evaluated within each pathway: health effects, waste reaching pathway, and population exposed. Within these categories, values for several factors are combined to form the category values (see Table B-11).

The health effects category is evaluated based on the toxicity of the contaminants on the site. The waste reaching pathway category is evaluated differently in the three pathways. Four subcategories are evaluated in the ground water and surface water pathway (three in the air pathway) depending on whether there is evidence of release from the site. The waste release subcategory is evaluated based on the factors listed in Table B-11 for each applicable pathway. The subcategory value is the sum of the factor values. In all three pathways, if evidence of release exists, the waste release subcategory value is then multiplied by 6 to form the waste reaching pathway value. If no evidence of release exists for the ground water or surface water pathways, the containment and

TABLE B-11

FACTORS INCLUDED IN ADL SYSTEM

Factors	Pathway Ground Water	Surface Water	Air
1. Health Effects			
Toxicity*	X	X	X
2. Waste Reaching Pathway			
A. Waste Released			
- Volatility			X
- Physical State*	X	X	
- Persistence*	X	X	
- Quantity*	X	X	X
- Net Precipitation*	X		
- 1-Year 24-Hour Rainfall*		X	
- Flood Potential		X	
- Exposed Site Area	X	X	X
B. Evidence of Release*	X	X	X
C. Containment*	X	X	
D. Waste Transported			
- Depth to Aquifer*	X		
- Distance to Surface Water*		X	
- Permeability*	X		
- Site/Slope Terrain*		X	
3. Population Exposed			
Water Use*	X	X	
Nearby Land Use*			X
Distance to Water Use*	X	X	
Distance to Land Use*			X
Population Affected*	X	X	X

*Factors common to both ADL system and HRS.

Source: Arthur D. Little, Inc., 1981.

GENERAL DESCRIPTION: (Concluded)

waste transported subcategories are evaluated. The containment value is simply 0 or 1, while the waste transported value is the sum of the values of the factors listed in Table B-11. The waste released, containment, and waste transported subcategory values are then multiplied to form the waste reaching pathway value. No such provision for evaluating sites lacking evidence of release is provided in the air pathway; in such cases the waste reaching pathway is assigned a score of zero.

The population exposed category is evaluated as the sum of the applicable factor values.

The overall pathway score is the product of the values for each of these three categories (normalized to the 0 to 100 scale).

SIMILARITIES TO HRS:

The ADL system and the HRS are similar in many respects. Taken together, the health effects and waste reaching pathway categories in the ADL system generally correspond to the HRS waste characteristics and release categories. Combinatorially, they are nearly identical. The ADL population exposed category is nearly identical to the HRS targets category. Also, both the ADL system and the HRS evaluate the pathway value as the product of the category values. Finally, both systems utilize many of the same factors in evaluating category values.

DIFFERENCES FROM HRS:

Despite the similarities between the two systems, there are differences between them. First, the overall site score in the ADL system is the sum of the pathway scores, while in the HRS, it is the root-mean-square of the pathway scores. Second, in the ADL system, persistence and quantity are effectively multiplied by the toxicity score (as are the remaining waste released values).

ARTHUR D. LITTLE, INC. (Concluded)

DIFFERENCES FROM HRS: (Concluded)

These factors are treated differently in the HRS; persistence is incorporated into the combined toxicity/persistence value, while the quantity value is added to the toxicity/persistence value. Third, the factor value scales for rating many of the factors differ between the systems. For example, quantity in the ADL ground water pathway is evaluated on a scale of 0 to 3, in increments of 1/2. In the HRS ground water pathway, quantity is evaluated on a scale of 0 to 8, in increments of 1. Since the scores in both systems are normalized, the only important distinction here is in the increments. Finally, three factors are included in the ADL system that are not in the HRS system: volatility (in the air pathway), flood potential (in the surface water pathway), and exposed site area.

CONCLUSIONS:

The ADL system was developed as a modification of the HRS. The ADL system was evaluated by EPA before they HRS was originally proposed and was found not to rank sites as well as the HRS. No further evaluation is warranted at this time.

REFERENCES:

Arthur D. Little, Inc., Proposed Revisions to MITRE Model, Arthur D. Little, Inc., Cambridge, MA, September 23, 1981.

DAMES AND MOORE

SYSTEM:	Rating and Risk Assessment Methodology
USER:	None identified
DEVELOPER:	Dames and Moore
USE/STATUS:	None identified
GENERAL DESCRIPTION:	This system is an adaptation of the rating methodology developed by JRB Associates, Inc. It employs the same four rating categories as the JRB methodology. Most of the factors within each rating category are identical to those in the JRB methodology, although there are some additions and deletions. This methodology differs from the JRB methodology (and the HRS) in that there is no aggregation of scores from the four rating categories. Instead, the score from each rating category is used to classify that rating category as posing a low or high risk. The low or high risk classifications assigned to the four rating categories are then combined to specify an overall site classification ranging from very low risk to very high risk (there are six such categories).
SIMILARITIES TO HRS:	The similarities discussed under the JRB methodology also apply to the Dames and Moore methodology. Similarities relate to common rating factors.
DIFFERENCES FROM HRS:	Most of the differences discussed under the JRB methodology also apply to the Dames and Moore methodology. In addition, the Dames and Moore methodology contains several rating factors not included in the HRS or the JRB methodology. These are carcinogenicity/mutagenicity/teratogenicity; bioaccumulation potential; type of evidence of contamination; seismic activity; and landfill cover condition, leachate management, free liquids, and personnel

DIFFERENCES FROM HRS: (Concluded) training. In addition, the method of aggregating the four rating categories differs as described above.

CONCLUSIONS: The Dames and Moore methodology is an adaptation of the JRB methodology that was considered in the development of the HRS. Thus, there is no need for further review of most of the components of the methodology. With regard to the additional rating factors indicated above, the factors are either not appropriate for inclusion in the HRS (e.g., personnel training) or not adequately defined in their present form for inclusion in the HRS (e.g., bioaccumulation potential).

REFERENCES:

Dames and Moore, Overview of Methodology for Rating the Potential for and Significance of Ground and Surface Water Contamination from Waste Disposal Sites, Bethesda, MD, Undated.

HAGERTY, PAVONI, AND HERR SYSTEM

SYSTEM: Hagerty, Pavoni, and Herr

USER: None identified

DEVELOPER: D. Hagerty, J. Pavoni, and J. Herr

USE/STATUS: No longer used

GENERAL DESCRIPTION: The Hagerty, Pavoni and Herr (HPH) system is an early ranking system (1973) that was intended to rate potential ground water impacts from landfilling of wastes. The HPH system produces two separate rankings, one based on waste characteristics and the other based on site and target characteristics. The former ranking uses five factors to rank the relative hazardousness (in ground water) of wastes that might be places in landfills (these factors are from the PHL model discussed in Appendix C). The latter ranking uses ten other factors to separately rank the potential of a landfill site itself to result in impacts via the ground water pathway. In both cases, computational equations are used to assign values to each factor. The factor values are summed to produce each type of ranking.

The factors used to rank waste hazardousness are: human toxicity, ground water toxicity, disease transmission potential, biological persistence, and waste mobility. The factor used to rank the potential of a site to cause ground water impacts are infiltration potential, bottom leakage potential, filtering capacity, adsorptive capacities, organic content of ground water, buffering capacity of ground water, travel distance, ground water velocity, prevailing wind direction, and population within 25 miles.

SIMILARITIES TO HRS: Two of the rating factors in the HPH system are similar to factors in the HRS. The HPH human toxicity factor is based on the Sax

HAGERTY, PAVONI, AND HERR SYSTEM (Concluded)

SIMILARITIES TO HRS: (Concluded)

rating scheme, as is the HRS toxicity factor. Both systems also include a factor for the population in the area of a site. However, the HPH system uses the total population within 25 miles of a site while the HRS considers only that population within three miles of the site that is using the aquifer of concern.

DIFFERENCES FROM HRS:

The HPH system applies only to ground water impacts from the landfilling of wastes. It is not intended to evaluate the relative threat posed by a site in terms of the site's route characteristics, waste characteristics, containment, and target. Rather, it was intended to identify wastes that may be of concern if they were landfilled and site locations that could be of concern if wastes were disposed there. Except for the two factors discussed under similarities to HRS, the other eight HPH factors do not specifically correspond to factors in the HRS. Also, the HPH system uses computational equations rather than factor scores to assign a value to each rating factor.

CONCLUSIONS:

The HPH is an early ranking system that was considered in the development of later ranking models. The additional factors in the HPH system that are not in the HRS are not adequately defined for inclusion in the HRS. The HPH system does not warrant any further evaluation.

REFERENCES:

Environ Corporation, Review and Analysis of Hazard Ranking Scheme, Final Report, May 11, 1984.

Seller, L. and L. Canter, Summary of Selected Ground Water Quality Impact Assessment Methods, National Center for Ground Water Research, Report No. NCGWR 80-3, Norman, OK, 1980.

JRB ASSOCIATES, INC.

SYSTEM:	Methodology for Rating the Hazard Potential of Waste Disposal Sites. Sometimes referred to as the Rating Methodology Model.
USER:	None currently identified. Model originally developed for EPA Office of Enforcement and the Oil and Special Materials Division for use in setting site investigation priorities based on preliminary assessment data. Model has been used as the basis for several other systems including the Rating Methodology Model (RMM), the Navy Confirmation Study Ranking System (CSRS), and the Dames and Moore system.
DEVELOPER:	JRB Associates, Inc.
USE/STATUS:	None identified.
GENERAL DESCRIPTION:	The JRB model consists of 31 rating factors grouped into four areas: receptors, pathways, waste characteristics, and waste management practices. These factors are listed in Table B-12. Each rating factor is scored on a scale of 0 to 3 and then multiplied by a factor-specific multiplier. These scores are then summed within each area to form an area subscore. The area subscores are then summed, divided by the maximum possible score, and multiplied by 100 to form the site score.
SIMILARITIES TO HRS:	The principal area of similarity between the JRB model and the HRS is in the common factors that both employ. These include depth to ground water, net precipitation, soil permeability, toxicity, waste quantity, persistence, reactivity, and incompatibility.
DIFFERENCES FROM HRS:	The JRB model and the HRS have a number of major differences. First, their overall structures are different. In the HRS, each pathway is treated separately; in the JRB model the pathways are combined into one scoring category. Furthermore, the JRB

TABLE B-12

JRB ASSOCIATES, INC. MODEL RATING FACTORS

Factor Category	Rating Factor
Receptor	Distance to nearest drinking-water well
	Distance to nearest off-site building
	Land use/zoning
	Critical environments
Pathways	Evidence of contamination
	Level of contamination
	Type of contamination
	Distance to nearest surface water
	Depth to ground water
	Net precipitation
	Soil permeability
	Bedrock permeability
	Depth to bedrock
Waste Characteristics	Toxicity
	Radioactivity
	Persistence
	Ignitability
	Reactivity
	Corrosiveness
	Solubility
	Volatility
	Physical state
Waste Management Practices	Site security
	Hazardous waste quantity
	Total waste quantity
	Waste incompatibility
	Use of liners
	Use of leachate collection systems
	Use of gas collection systems
	Use and condition of containers

Source: Kufs et al., 1980a.

DIFFERENCES FROM HRS: (Concluded)

model does not address the air pathway. Also, containment is treated as a single factor, not as a pathway specific factor. Second, the scores are combined in different fashions in the two systems. In the JRB model, the site score is a weighted sum of the factor scores while the HRS site score is the root mean square of weighted sums of factor scores. Thus, the JRB model is a linear model, the HRS is not. Finally, the JRB model includes a number of factors in the ranking that the HRS does not, e.g., bedrock permeability, depth to bedrock, waste ignitability, corrosiveness, and volatility. There are numerous other less important differences between the two systems.

CONCLUSIONS:

The JRB model was assessed during the development of the HRS (47 FR 10975, March 12, 1982). The additional factors present in the JRB model, but not in the HRS, were considered during development of the HRS but were rejected because they could not be adequately defined for use in the HRS or because other factors were judged to provide better measures of relative risk.

REFERENCES:

Kufs, Charles et al., Methodology for Rating the Hazard Potential of Waste Disposal Sites, (Draft Final Report), JRB Associates, Inc., McLean, VA, May 5, 1980a.

Kufs, Charles et al., "Rating the Hazard Potential of Waste Disposal Sites," Proceedings of the National Conference on Management of Uncontrolled Hazardous Waste Sites, held on October 15-17, 1980 in Washington, DC, Hazardous Materials Control Research Institute, Silver Spring, MD, 1980b, pp. 30-41.

THE LEGRAND SYSTEM

SYSTEM: Untitled

USER: No specific users could be identified. Modifications of the current LeGrand system (and its predecessor) are used by the State of Connecticut and in the Olivieri and Eisenberg Assessment Methodology

DEVELOPER: Harry E. LeGrand

USE/STATUS: Designed to evaluate the acceptability of locations for use as possible disposal sites.

GENERAL DESCRIPTION: The LeGrand system is designed to evaluate the acceptability of a proposed disposal site based on the potential for ground water contamination at the site. The system produces a vector of site characteristics (i.e., the "site description") to be used in the evaluation process. The complete evaluation process is not algorithmic, but provides for subjective judgment based on the factors contained in the site description. The site description is based on the following characteristics:

- Distance between contamination source and water supply
- Depth to water table
- Water table gradient
- Permeability-sorption
- Confidence in accuracy of results
- Miscellaneous identifiers

Each of these characteristics is evaluated on a separate scale which is adapted from the original LeGrand system (LeGrand, 1964).

A combined numerical rating for the site is calculated as the sum of the ratings for the first four characteristics listed above. An additional factor is included based on the degree of seriousness of the hazard using a hazard potential matrix. The degree of

GENERAL DESCRIPTION: (Concluded)

seriousness is evaluated based on the degree of aquifer sensitivity and the degree of contaminant severity. The former factor is evaluated based on the type of geologic material underlying the site. The latter is based either on the source of the wastes (e.g., organic or inorganic chemical manufacturing) or the type of wastes (e.g., municipal waste) to be disposed of on the site. The inclusion of the degree of seriousness factor completes the "natural" site description (see Table B-13).

The aquifer sensitivity and contaminant severity factors are also used to define the "PAR" site description, a numerical vector describing a benchmark for interpreting the natural site description. The PAR vector is subtracted from the natural vector and the resulting vector summed (as applicable) to form the situation rating. The situation rating is then used in a rating table to assess, qualitatively, the probability of contamination and the degree of acceptability of the site. Engineering characteristics of the site can be reflected in the PAR description and hence in the situation rating, although the exact procedures for doing so are not provided in the references.

SIMILARITIES TO HRS:

There are few similarities between the LeGrand system and the HRS. Both systems use some common factors (e.g., distance between site and water supply, and depth to ground water) and both systems distinguish between the type of receiving water body (e.g., well or stream). Finally, both systems evaluate the probability that the site will contaminate the ground water. In all cases, however, the two system treat these factors differently.

TABLE B-13

SUMMARY EXAMPLE OF LEGRAND SITE DESCRIPTIONS FOR A COUNTY LANDFILL IN THE NORTH CAROLINA PIEDMONT

Factor	Factor Value
• Distance between contamination source and water supply (2,200 feet)	2
• Depth to water table (less than 2 feet)	8
• Water table gradient (less than 2 percent)	3
• Permeability-sorption (30 feet sandy clay soil and soft rock over poorly permeable consolidated rock)	4F
• Confidence in accuracy of results	B
• Miscellaneous	
(Creek as contamination target)	S
(Other factors: potential for mounding)	M
• Sum of first four numerical values (2 + 8 + 3 + 4 = 17)	17
• Site Numerical Description (i.e., all of the above factor values)	17 2 8 3 4F B S M
• Aquifer sensitivity (moderately fractured crystalline rock)	Moderately sensitive
• Contaminant Severity (municipal landfill)	Moderately high
• Degree of Seriousness (moderately high)	E
• "Natural" Site Description	17 2 8 3 4F B S M +E
• "PAR" Site Description	16 2 4
• Situation Rating	1 E
• Probability of Contamination	Unknown
• Acceptability	Unknown

Source: LeGrand, 1980.

DIFFERENCES FROM HRS: There are numerous differences between the two systems. First, the LeGrand system is not a ranking system. It provides a semi-numerical description of a site to be used by decision-makers to evaluate the acceptability of the site for use as a waste disposal site. Second, the LeGrand system addresses the potential for ground water contamination only. No consideration is given to the potential for surface water, air, or soil contamination. Third, the LeGrand system does not consider the potential impact of the contamination on human health. No consideration is given to the types and numbers of potential contamination targets. Fourth, the LeGrand system provides a nonquantitative assessment of the accuracy of the rating. No such factor is included in the HRS. Fifth, many of the factors in the LeGrand system are very subjective or nonquantitative, e.g., the degree of aquifer sensitivity and contaminant severity. Sixth, the LeGrand system does not consider the actual degree of the hazard posed by the waste contaminants at the site. Contaminant severity is assessed using vague, non-site-specific waste classes. Finally, the LeGrand system contains some factors not included in the HRS, particularly, water table gradient and sorption potential.

CONCLUSIONS: The LeGrand system and the HRS are very different systems, both in their structures and in the uses for which they were developed. The LeGrand system can be modified or adapted to assist in ranking uncontrolled wastes sites and has been used in such a fashion as indicated above.

The concepts embedded in three factors in the LeGrand system should be evaluated further. These are the permeability-sorption factor, the aquifer sensitivity factors and the water

CONCLUSIONS: (Concluded)

table gradient factor. These factors, however, are not themselves adequately defined for use in the HRS. In addition, the concept of including a qualitative assessment of the accuracy of the rating results should be investigated further.

REFERENCES:

LeGrand, Harry E., A Standardized System for Evaluating Waste-Disposal Sites: A Manual to Accompany Description and Rating Charts, National Water Well Association, 1980.

LeGrand, H. E., "System for Evaluation of Contamination Potential of Some Waste Disposal Sites," JAWWA, 1964, pp. 959-974.

MONROE COUNTY METHODOLOGY

SYSTEM:	Monroe County Methodology (MCM)
USER:	Monroe County Environmental Management Council, Rochester, NY
DEVELOPER:	Monroe County Environmental Management Council and State University of New York (SUNY) at Geneseo under contract to U.S. EPA Environmental Monitoring Systems Laboratory, Las Vegas, NV
USE/STATUS:	Currently used by Monroe County Environmental Management Council to identify and assign priorities to sites for future investigation.
GENERAL DESCRIPTION:	The MCM is intended to supplement ranking systems such as LeGrand and JRB by identifying and ranking sites that might be contaminated with hazardous wastes for further investigation. The MCM uses historic aerial photographs as primary data, supplemented by other data. Based on the historic record, sites are identified and classified into six site activity categories: identifiable, possible, unspecified, lagoons, auto junkyards and salvage areas, and suspicious. A site activity record is then compiled. The site activity record covers a large number of factors including the historic activity at site based on photos, site acreage, record of disposal activity, type of waste disposed (e.g., acids, radioactive waste, herbicides), adjacent land use, well information, site features (e.g., depth to ground water). A geologic analysis of the area is performed leading to development of geologic overlay maps. A geologic ranking sheet is prepared addressing: overburden geology, estimated permeability, relief/geomorphology, depth to ground water, ground water gradient, bedrock character, soil properties, texture and behavior. The geologic ranking system is based on the presumed effect on the overall hazard that

GENERAL DESCRIPTION: (Concluded)

each geologic factor would have: increase hazard, intermediate (uncertain), decrease hazard. A decision on how to proceed with the site is made based on the site activity record combined with the geologic ranking and an assessment of the threat to drinking water. For example, a decision to conduct a complete monitoring program would be made for a site with a history of waste disposal, a high geologic ranking and an identified threat to ground water. Sites that could impact nearby wells are immediately referred to authorities for testing. Other sites are prioritized using a matrix for ranking geologic and land use impact, size and type of activity. Information on this matrix procedure is not available in the reference.

SIMILARITIES TO HRS:

The MCM addresses some of the same factors as the HRS, e.g., depth to ground water, distance to nearest well.

DIFFERENCES FROM HRS:

The MCM is designed to identify and rank sites that might contain hazardous waste for further investigation. It is thus intended to be applied at an earlier stage than the HRS. The MCM addresses ground water only and thus is more dependent on geologic data/factors. The system does not apparently produce a single score for a site but rather classifies sites and prioritizes them based on their classification. The two systems are not directly comparable.

CONCLUSIONS:

The geologic ranking system appears to warrant further evaluation for possible application to the HRS.

REFERENCES:

Nelson, Ann R., Louise A. Hartshorn and Richard A. Young, A Methodology to Inventory, Classify, and Prioritize Uncontrolled Waste Disposal Sites (EPA-600/4-83-050), Environmental Monitoring Systems Laboratory, U.S. Environmental Protection Agency, Las Vegas, NV, October 1983.

REFERENCES: (Concluded)

Nelson, Ann B. and Richard A. Young, "Location and Prioritizing of Abandoned Dump Sites for Future Investigations," Proceedings of the National Conference on Management of Uncontrolled Hazardous Waste Sites, held on October 28-30, 1981 in Washington, DC, Hazardous Materials Control Research Institute, Silver Spring, MD, 1981, pp. 52-62.

OLIVIERI AND EISENBERG ASSESSMENT METHODOLOGY

SYSTEM: Untitled

USER: San Francisco Regional Water Quality Control Board and the Santa Clara Valley Water District

DEVELOPER: Dr. Adam W. Olivieri and Dr. Don M. Eisenberg

USE/STATUS: Currently used by the San Francisco Regional Water Quality Control Board to rank hazardous material contamination sites in terms of their relative potential for ground water contamination.

GENERAL DESCRIPTION: The Olivieri and Eisenberg assessment methodology is designed to rank hazardous material contamination sites containing organic solvents in terms of their relative potential for ground water contamination.

Sites are ranked with regard to two areas: site sensitivity and contamination severity. Site sensitivity rates the susceptibility of the site to ground water contamination. Site sensitivity is rated using four factor categories that have been developed based on the LeGrand system (see Table B-13). Table B-14 lists the four factor categories and the 14 specific hydrogeologic and water use factors within these factor categories.

Contamination severity rates the severity and potential for the release from the site to contaminate ground water. Contamination severity is rated using three factor categories. Table B-14 lists the three factor categories and the nine specific factors within these factor categories. Four of these factors, the three toxicity factors and the bioaccumulation factor, are based upon the chemical hazard rating scheme developed by the State of Michigan (see Figure B-6 and Table B-8).

TABLE B-14

OLIVIERI AND EISENBERG ASSESSMENT METHODOLOGY RATING FACTORS

SITE SENSITIVITY FACTORS

Distance to Point of Water Use

- Closest Public Well Downgradient
- Closest Public Well Not Downgradient
- Closest Private Well Downgradient

Intensity of Present Water Use

- Population Served by Wells in the Downgradient Square Mile
- Number of Public Wells within 1,500 Feet Downgradient
- Number of Private Wells beyond 1,500 Feet Downgradient, but Within 1 Square Mile
- Number of Private Wells Within 1 Square Mile Downgradient

Depth to Water Table

- Depth to Shallowest Ground Water
- Depth to Shallowest Useable Ground Water (Potential Supply)
- Depth to Shallowest Currently-Used Potable Water (Existing Supply)
- Permeability (Travel Time) of Zone 0 to 50 Feet Below Surface
- Permeability (Travel Time) of Zone 50 to 150 Feet Below Surface
- Permeability (Travel Time) of Zone 150 to 300 Feet Below Surface

Gradient of Shallow Water Table

- Ground Water Table Gradient

CONTAMINANT SEVERITY FACTORS

Toxicity

- Acute
- Chronic
- Mutagenic

TABLE B-14 (Concluded)

CONTAMINANT SEVERITY FACTORS (Concluded)

Physical-Chemical Properties

- Soil Sorption
- Bioaccumulation

Magnitude of Contamination

- Highest Contaminant Concentration in Ground Water
- Highest Contaminant Concentration in Soil
- Contaminant Plume Dimension
- Number of Chemicals

Source: Olivieri and Eisenberg, 1985.

GENERAL DESCRIPTION: (Concluded)

The scores for each factor are summed to give site sensitivity and containment severity ratings. At the user's discretion, these two ratings may either be summed to give one overall rating for the site or may be used separately in a two-dimensional graphical display as an aid to ranking the site.

SIMILARITIES TO HRS:

The Olivieri and Eisenberg Assessment Methodology is intended to evaluate the relative ground water threat posed by sites containing organic solvents. As such, the methodology corresponds to the HRS ground water pathway. The Olivieri and Eisenberg Assessment Methodology and the HRS contain five types of factors that are similar in concept, but which are defined, evaluated, and weighted differently. These are: distance to nearest well, population served by wells, depth to aquifer, permeability, and toxicity.

DIFFERENCES FROM HRS:

There are several major differences between the Olivieri and Eisenberg Assessment Methodology and the HRS. First, the assessment methodology applies only to the ground water pathway and only to releases of organic solvents. Second, the methodology uses different definitions and measures for factors that are similar in concept to those in the HRS. Third, the methodology contains several factors that are not present in the HRS, e.g., contaminant carcinogenicity, contaminant mutagenicity, contaminant bioaccumulation potential, plume dimension, highest contaminant concentration in plume or soil, number of chemicals present, gradient of ground water table, and soil sorption constant. Finally, the methods used to combine factor scores to form the overall site scores differs between the systems. The Olivieri and Eisenberg methodology is additive. Further, the actual method of calculating the site score from the site

DIFFERENCES FROM HRS: (Concluded)

sensitivity and contaminant severity scores is left up to the user. The HRS sums within categories, but multiplies the category values to form the pathway values. Additionally, the HRS utilizes a root-mean-square calculation to form the site score.

CONCLUSIONS:

The factors listed above that are contained in the this methodology, but not in the HRS, should be examined for possible application in the HRS.

REFERENCES:

Olivieri, Adam W. et al., Assessment of Contamination from Leaks of Hazardous Materials in the Santa Clara Basin 205j Report, San Francisco Regional Water Quality Control Board, SEEHRL University of California, Berkeley and Santa Clara Valley Water District, February 1985.

Olivieri, A. W. and D. M. Eisenberg, "A Methodology for Ranking Risk of Groundwater Contamination from Hazardous Material Sites," ASCE National Conference on Environmental Engineering, Los Angeles, CA, June 25-27, 1984.

PHILLIPS, NATHWANI, AND MOOIJ MATRIX

SYSTEM: Phillips, Nathwani, and Mooij

USER: None identified

DEVELOPER: C. Phillips, J. Nathwani, and H. Mooij

USE/STATUS: No current uses could be identified.

GENERAL DESCRIPTION: The Phillips, Nathwani, and Mooij (PNM) matrix is intended to rank potential ground water impacts from the land disposal of wastes. The PNM matrix produces three types of rankings: a waste hazardousness ranking, a soil-site ranking (which corresponds to the HRS ground water route characteristics category), and a combined waste-soil-site ranking. Ten factors (4 of which are modified from the PHL model discussed in Section C.1 of Appendix C) are used to rank the relative hazardousness (in ground water) of wastes that might be land disposed. Seven other factors (6 of which are modified from the LeGrand Model) are used to rank the potential of a land disposal site to result in impacts to ground water. The 17 factors are confined in a matrix to rank the waste-soil-site interaction. Computational equations are used to assign values to each factor.

The six factors not included in the PNL model that are used to rank waste hazardousness are: chemical persistence, sorption, viscosity, solubility, acidity/basicity, and waste application rate. The one soil-site factor not included in the LeGrand model is infiltration.

SIMILARITIES TO HRS: The similarities discussed under the PHL model and the LeGrand model also apply to the PNM matrix. Similarities relate to common rating factors.

DIFFERENCES FROM HRS: The differences discussed under the PHL model and the LeGrand model also apply to the PNM

DIFFERENCES FROM HRS: (Concluded)

matrix. Furthermore, the PNM matrix contains six additional rating factors noted above that are not included in the HRS or the other two models. In addition, the PNM matrix applies only to ground water impacts from the land disposal of wastes. In evaluating land disposal sites, the PNM matrix considers only route characteristics and waste characteristics. Targets and waste containment factors are not considered. The PNM matrix also uses computational equations rather than factor scores to assign a value to each rating factor. Furthermore, several factors require data derived from site-specific field experiments before they can be scored (e.g., sorption, chemical persistence).

CONCLUSIONS:

The additional factors in the PNM matrix that are not in the HRS are not adequately defined for inclusion in the HRS. The PNM matrix does not warrant any further evaluation.

REFERENCES:

Seller, L. and L. Canter, Summary of Selected Ground Water Quality Impact Assessment Methods, National Center for Ground Water Research, Report No. NCGWR 80-3, Norman, OK, 1980.

RATING METHODOLOGY MODEL

SYSTEM: Rating Methodology Model

USER: None identified

DEVELOPER: Undetermined. Apparently based on JRB Associates, Inc. model.

USE/STATUS: None could be identified. Model as presented in reference is not useable.

GENERAL DESCRIPTION: The Rating Methodology Model (RMM) is an adaptation of the JRB Associates, Inc. model and is designed to evaluate the risk of hazardous waste sites and to produce a single score reflecting this risk. The RMM incorporates four types of factors: receptors, pathways, waste characteristics, and waste management practices. Little information is available in the reference on the factors and computational approaches employed in the RMM. In the model, scores are determined for each of several evaluation parameters. These parameter scores are multiplied by weighting factors to form site parameter scores. These site parameters scores are then summed and normalized to form a site score.

SIMILARITIES TO HRS: Most of the factors identified in the RMM appear to be addressed in the HRS. Receptor parameters appear to include population and facilities, land and water use, critical habitats and biota. Pathways appear to include air, water and soil. Waste characteristics common to both the RMM and HRS appear to include quantity, condition of wastes, toxicity, ignitability, reactivity, corrosivity and persistence. See JRB Associates, Inc. for a further discussion of similarities.

DIFFERENCES FROM HRS: The RMM considers more waste characteristics than the HRS: mobility, carcinogenicity, volatility, radioactivity, and solubility.

DIFFERENCES FROM HRS: (Concluded)

The computational approach appears to be different; the score is based on the sum of the site parameter scores rather than on the product of pathway scores, as in the HRS. See JRB Associates, Inc. for a further discussion of differences.

CONCLUSIONS:

The model appears to be more of a general approach for a ranking system rather than a ranking system itself. The operational definition of the additional waste characteristics that appear in RMM are not adequate for consideration in the HRS.

REFERENCES:

Berger, Isabell S., "Determination of Risk for Uncontrolled Hazardous Waste Sites," Proceedings of the National Conference on Management of Uncontrolled Hazardous Waste Sites, held on November 29-December 1, 1982 in Washington, DC, Hazardous Materials Control Research Institute, Silver Spring, MD, 1982, pp. 23-26.

TRC ENVIRONMENTAL CONSULTANTS, INC.

SYSTEM:	Untitled. Author refers to approach as an Objective Calculation Procedure (OCP).
USER:	None has been identified. System is presented in conference proceedings.
DEVELOPER:	TRC Environmental Consultants, Inc., under subcontract to GCA/Technology Division, which is under contract to EPA.
USE/STATUS:	None could be identified. System as presented in reference is not useable.
GENERAL DESCRIPTION:	The author presents a calculation equation designed to estimate the total risk from a waste site over a defined time period. The equation reflects the potency of chemicals released, the relationship between ambient concentrations of the chemicals and the ingestion/inhalation rates of the chemicals, population and the exposure concentration. The author also compares his equation to the approach taken in the HRS.
SIMILARITIES TO HRS:	Many of the factors included in the HRS are reflected in the OCP. For example, in the ground water pathway, the OCP reflects observed release, route characteristics, containment, physical state of the waste, contaminant persistence, contaminant toxicity/infectiousness, waste quantity, ground water use, target population and distance to nearest well downgradient.
DIFFERENCES FROM HRS:	The OCP is not a scoring system but can be used as the basis for one. The author states that the OCP does not discount future risks while the HRS "strikes a balance" by combining scores for waste quantity and release rate. The author also states that the OCP emphasizes "what is right" about a site while the HRS emphasizes "what is wrong" with the site.

TRC ENVIRONMENTAL CONSULTANTS, INC. (Concluded)

CONCLUSIONS:

The OCP presents a risk-based alternative to the value-based approach taken in the HRS. Its concept could be implemented, but is subject to more severe data availability problems than the HRS. The equations presented are also significantly simplified, possibly too much to be acceptable. Some of the factors included in the OCP should be reviewed for inclusion in the HRS (e.g., contaminant mobility); however, the approach taken in the OCP is incompatible with the HRS.

REFERENCES:

Murphy, Brian L., "Abandoned Site Risk Assessment Modeling and Sensitivity Analysis," Proceedings of the National Conference on Management of Uncontrolled Hazardous Waste Sites, held on November 29-December 1, 1982 in Washington, DC, Hazardous Materials Control Research Institute, Silver Spring, MD, 1982, pp. 396-398.

APPENDIX C

CHEMICAL HAZARD RANKING SYSTEMS

Section C.1 contains summaries for seven systems developed for use in ranking chemical hazards. Each summary contains information on the following topics:

- Name
- User
- Developer
- Use/Status
- General Description
- Similarities to HRS
- Differences from HRS
- Conclusions
- References

Section C.2 identifies 52 other chemical hazard ranking systems.

C.1 Individual Systems Summaries

This section presents individual summaries of seven chemical hazard ranking systems:

- Action Alert System
- Barring Model
- CERCLA Reportable Quantities
- Clement Associates
- PHL Model
- RCRA Hazardous Waste Scheduling Methodology
- Superfund Public Health Evaluation System

ACTION ALERT SYSTEM

SYSTEM:	Action Alert System
USER:	United States Environmental Protection Agency, Monitoring and Data Support Division, Office of Water Regulations and Standards.
DEVELOPER:	Arthur D. Little, Inc.
USE/STATUS:	The Action Alert System was designed and used as a planning tool to evaluate 129 priority pollutants. It is no longer being used.
GENERAL DESCRIPTION:	The Action Alert System was developed as a preliminary screening tool for use in prioritizing chemicals, primarily the 129 priority pollutants, for further study or regulatory action based on the potential risk they pose to humans and aquatic life. The Action Alert System was intended to provide a rapid and consistent mechanism for screening chemicals based upon partial information about their presence in the environment and the associated potential hazards. The screening provides either a qualitative indication of the degree of concern warranted for each chemical (i.e., low or high) or a specification of the additional data required to make such a determination.
SIMILARITIES TO HRS:	None, see differences.
DIFFERENCES FROM HRS:	The Action Alert System is intended to prioritize chemicals for further study or regulatory action based on risk approximations. It is not intended to rank the threat posed by waste sites, nor even to rank the degree of hazard of various chemicals.
CONCLUSION:	The Action Alert System is not applicable to ranking the potential threat posed by hazardous waste sites.

ACTION ALERT SYSTEM (Concluded)

REFERENCES:

U.S. Environmental Protection Agency, An Approach to Prioritization of Environmental Pollutants: The Action Alert System, Final Draft Report, U.S. Environmental Protection Agency, June 1980 (revised January 1982).

Slimak, Mike, U.S. Environmental Protection Agency, personal communication to Carol Burger, The MITRE Corporation, September 18, 1986.

BARRING MODEL

SYSTEM:	Barring Model
USER:	Environmental Protection Agency
DEVELOPER:	Booz-Allen Applied Research, Inc.
USE/STATUS:	No longer used.
GENERAL DESCRIPTION:	The Barring Model is an early hazard ranking model (1973) that was intended to identify a representative list of hazardous substances and to rank the effects of these substances in terms of air, water, and land pollution hazards. Four factors addressing toxic effects to human and other populations, flammable hazard, explosive hazard, and reactive hazard were used to calculate a Total Effects Rating (TER) for a hazardous substance. The TER was a weighted sum of the four factors values. The Hazard Rating was calculated as the product of the TER and a Hazard Extent Rating which was based on annual production and consumer distribution of the hazardous substances. Over 500 substances, many of which were warfare agents, were rated using the model.
SIMILARITIES TO HRS:	Several of the factors in the Barring Model are similar to some of the factors in the waste characteristics category of the HRS air and fire and explosion pathways (e.g., toxicity, reactivity). However, they are not specified or weighted in the same way.
DIFFERENCES FROM HRS:	There are a number of differences between the HRS waste characteristics categories and the Barring Model. The most important is that by the nature of its ranking factors, the Barring Model seems intended to focus on ranking explosive and ignitable wastes rather than on ranking the many types of hazardous substances present at release sites. Its application primarily to warfare agents provides further evidence of this focus.

BARRING MODEL (Concluded)

CONCLUSION: The Barring Model was an early ranking model that was considered in the development of more recent ranking models. It does not warrant any further evaluation.

REFERENCES: Environ Corporation, Review and Analysis of Hazard Ranking Schemes, Final Report, May 11, 1984.

CERCLA REPORTABLE QUANTITIES (RQ)

SYSTEM: Reportable Quantities

USER: Environmental Protection Agency, Office of Solid Waste

DEVELOPER: Environmental Monitoring and Services, Inc.

USE/STATUS: Used to determine quantities of releases that must be reported to EPA pursuant to Sections 102(a) and 102(b) of CERCLA.

GENERAL DESCRIPTION: The purpose of this system is to determine the minimum quantity of a hazardous substance spill or release that must be reported to EPA. Initially, each substance is assigned a vector of RQ values based on its reactivity, ignitability, acute toxicity, aquatic toxicity, and chronic toxicity.

Reactivity is evaluated based on the ability of the substance to react with water and/or itself. RQ values for reactivity range from 10 to 5,000. Ignitability is evaluated, using the same scale as reactivity, based on the flash point and boiling point of the substance. Acute toxicity is evaluated based on the LC_{50} or LD_{50} of the substance administered by ingestion, inhalation, or dermal contact, as applicable. Acute toxicity values range from 1 to 5,000. For example, substances with an oral LD_{50} less than 0.1 mg/kg, a dermal LD_{50} less than 0.04 mg/kg, or an inhalation LC_{50} less than 0.04 ppm are assigned an RQ value of 1. The acute toxicity value for a substance is the minimum of the values for its possible exposure routes. Aquatic toxicity is evaluated using the LC_{50} of the substance, again on the full scale of 1 to 5,000. The method for evaluating chronic toxicity is more complex. Chronic toxicity is evaluated based on a composite of the overall minimum effective dose (MED) of the substance for the three possible exposure

GENERAL DESCRIPTION: (Concluded)

routes (ingestion, inhalation, and dermal) and a numerical assessment of the severity of the effects caused by repeated or continuous exposure. MED is converted to a scale of 1 to 10, using the inverse of the logarithm of the MED. Severity is also evaluated on a scale of 1 to 10, with minor effects being assigned low scores and major effects, high scores.

The product of the MED and severity scores is calculated and an RQ value is assigned using the following scale:

1 to 5:	RQ = 5000
6 to 20:	RQ = 1000
21 to 40:	RQ = 100
41 to 80:	RQ = 10
81 to 100:	RQ = 1

The lowest of the RQ values determined for the five criteria is taken as the "primary criteria" RQ value. This value may then be adjusted, based on the persistence of the substance in the environment to obtain the statutory RQ value. Persistence is defined in terms of the potential of the substance for undergoing biodegradation, hydrolysis, and photolysis.

SIMILARITIES TO HRS:

There are three areas of similarity between the RQ system and the HRS waste characteristics evaluation procedure. First, both systems consider the acute toxicity of a substance. Also, both systems consider chronic toxicity, the RQ systems explicitly, the HRS implicitly to the extent that Sax considers it. The second similarity lies in the way that each considers acute toxicity. Both systems assign values to substance based on the LD_{50} or LC_{50} of the substance, as applicable, although the two systems use different scales. Finally, both systems address the ignitability and reactivity of substances.

DIFFERENCES FROM HRS: There are several important differences between the systems. First, as stated above, the procedures used in evaluating the common factors are different in some details. Second, and more importantly, the RQ system considers a number of chronic effects (including teratogenicity) not addressed in Sax, and hence excluded from consideration in the HRS. Third, the HRS employs different values depending on the migration pathway under consideration. The RQ system does not consider migration pathways, only modes of exposure. Further, the HRS assumes a direct relationship between the mode of exposure and the migration pathway, e.g., ingestion is assumed to be the mode of exposure in the ground water pathway while inhalation is assumed in the air pathway. Given this assumption, the HRS treats modes of exposure separately while the RQ value is based on the minimum of the values for the potential modes of exposure.

CONCLUSIONS: The RQ system contains many features that are either addressed indirectly or lacking in the HRS waste characteristics category. The systems should be evaluated in detail.

REFERENCES:

Environmental Monitoring and Services, Inc., Technical Background Document to Support Rulemaking Pursuant to CERCLA Section 102, Volume 1, U.S. Environmental Protection Agency, Washington, DC, 1985.

48 FR 12552, May 25, 1983.

50 FR 13456, April 4, 1985.

CLEMENT ASSOCIATES

SYSTEM: Untitled

USER: Clement Associates, Inc.

DEVELOPER: Clement Associates, Inc.

USE/STATUS: The system has been used to determine the relative risk ranking of 32 chemicals.

GENERAL DESCRIPTION: The methodology provides a score for a pollutant that represents the relative probability that a given hazard will occur in exposed populations per unit dose of the pollutant. The effects that are scored are carcinogenicity, teratogenicity, reproductive toxicity, mutagenicity, hepatotoxicity, renal toxicity, neurobehavioral toxicity and effects in other organ systems. A score is assigned for each of these forms of toxicity for each pollutants. The score is a product of two measures of risk:

- Probability that the pollutant is toxic to humans, based on inferences from animal data, or on direct measures of human toxicity.

- Probability of occurrence of the toxic effect in exposed humans per unit dose of exposure, assuming that the agent is a human toxicant.

SIMILARITIES TO HRS: The sole similarity between the Clement Associates, Inc. system and the HRS is that both reflect acute toxicity.

DIFFERENCES FROM HRS: The methodology is an alternative to the Sax rating scheme used in the HRS toxicity factor.

CONCLUSIONS: The methodology needs to be further evaluated to assess its applicability to the HRS.

REFERENCES: Clement Associates, Inc., Toxics Integration Program: Scoring of Selected Pollutants for Relative Risk, Washington, DC, June 26, 1981.

PHL MODEL

SYSTEM: PHL Model

USER: None has been identified.

DEVELOPER: J. Pavoni, D. Hagerty, and L. Lee

USE/STATUS: No longer used.

GENERAL DESCRIPTION: The PHL Model is an early ranking model (1972) that was intended to rank the hazardousness of substances placed in landfills. The model consists of five ranking factors that were summed: toxicity, ground water toxicity, disease transmission potential, biodegradability, and mobility. Computational equations were used to assign a value to each factor.

SIMILARITIES TO HRS: The toxicity factor in the PHL Model is based on the Sax rating schemes.

DIFFERENCES FROM HRS: The PHL Model applies only to substances placed in landfills. It contains three factors not included in the HRS: disease transmission potential, ground water toxicity, and mobility. Ground water toxicity of a substance is calculated based on the smallest concentration known to have caused injury to man or biota. Mobility is calculated based on the ionic charge or net charge of a substance. The PHL Model also uses computational equations rather than factor scores to assign a value to each rating factor.

CONCLUSIONS: The PHL is an early ranking model that was considered in the development of later ranking models. It does not warrant any further evaluation.

REFERENCES:

Environ Corporation, Review and Analysis of Hazard Ranking Schemes, Final Report, May 11, 1984.

RCRA HAZARDOUS WASTE SCHEDULING METHODOLOGY

SYSTEM: RCRA Hazardous Waste Scheduling Methodology

USER: Environmental Protection Agency, Office of Solid Waste

DEVELOPER: Environ Corporation

USE/STATUS: The methodology has been proposed by EPA to be used to schedule RCRA listed hazardous waste streams for land disposal prohibition determinations, as required by the Hazardous and Solid Waste Amendments of 1984. The methodology was proposed in the Federal Register (50 FR 23250, May 31, 1985) and has not yet been promulgated as final.

GENERAL DESCRIPTION: The methodology ranks the toxic potential of waste constituents. The toxicity ranking scheme incorporates measures of both acute and chronic toxicity and can be applied to a broad range of chemicals with a wide variety of data bases. The LD_{50} is used as a measure of acute toxicity. The chronic toxic potential of a compound is summarized in a single term, designated the Equivalent Dose Estimate (EDE). Acceptable daily intakes (ADIs) and unit cancer risks (UCRs) serve as the basis for deriving the EDEs for noncarcinogenic and carcinogenic compounds, respectively. For those compounds with limited data bases, additional uncertainty factors are applied to derive the EDE. For compounds with extremely limited data bases, EDEs are assigned by analogy to structurally similar compounds or are estimated by applying a large standardization factor to a measure of acute toxicity. The waste constituents are assigned a chronic toxicity score of 1 to 9 based on the estimate of chronic toxic potential (the EDE). This score is adjusted upward by 1 if a compound possesses high acute toxicity according to the established criteria. Thus, the resulting toxicity scores range from 1 to 10.

RCRA HAZARDOUS WASTE SCHEDULING METHODOLOGY (Concluded)

SIMILARITIES TO HRS:	The EDE is an alternative to the Sax rating scheme used in the HRS toxicity factor.
DIFFERENCES FROM HRS:	The EDE is based on ADIs and UCRs and not on the Sax rating scheme. As such it is an alternative to the HRS toxicity factor.
CONCLUSIONS:	The methodology needs to be further evaluated for possible application in the HRS.
REFERENCES:	Environ Corporation, <u>Documentation for the Development of Toxicity and Volume Scores for the Purpose of Scheduling Hazardous Wastes, Final Report</u>, Washington, DC, March 28, 1985.

SUPERFUND PUBLIC HEALTH EVALUATION (SPHE) SYSTEM

SYSTEM: Superfund Public Health Evaluation (SPHE) System

USER: U.S. Environmental Protection Agency, Office of Solid Waste

DEVELOPER: ICF Incorporated

USE/STATUS: Used to evaluate the threat to public health from NPL sites and to develop remedial action goals.

GENERAL DESCRIPTION: The SPHE system is a method for estimating the public health impacts of NPL sites. It is used as part of the remedial response process, as an aid in identifying, evaluating, and selecting remedial alternatives. As such, it is not a chemical hazard ranking system. However, Step 1 of the SPHE system addresses the selection of chemicals, from among all those chemicals at the site, as "indicator chemicals" to be used in further site evaluation. This portion of the system was examined as a chemical hazard ranking system.

The SPHE system uses an "indicator score" to identify indicator chemicals. The indicator score is the product of the measured (or estimated) concentration of the chemical at the site times a "toxicity constant." These toxicity constants are benchmark ambient concentrations derived separately for air, water, and soil. The toxicity constants are in units of inverse concentration (e.g., 1/mg or m^3/mg). Separate toxicity constants are carcinogenic and noncarcinogenic effects. Thus, a particular chemical may have as many as six toxicity constants; one for carcinogenic effects in each of three routes and one for noncarcinogenic effects in each of three routes. Acute toxicity is not considered in the SPHE system.

GENERAL DESCRIPTION: (Concluded)

Noncarcinogenic toxicity factors are derived using estimates of the minimum effective dose ($MED_{(oral)}$ or $MED_{(inhalation)}$, as applicable) of the chemical that induces an irreversible effect and the severity factor (RV_e) developed for the chemical as part of the CERCLA Reportable Quantities (RQ) system. The route-specific noncarcinogenic toxicity constants are calculated as follows:

water: $w_{tn} = 2 \times RV_e/MED_{(oral)}$

soil: $s_{tn} = 0.0001 \times RV_e/MED_{(oral)}$

air: $a_{tn} = 20 \times RV_e/MED_{(inhalation)}$

Carcinogenic toxicity constants are derived in a similar fashion using the dose to experimental animals that induces a particular tumor to occur in 10 percent more of the exposed animals than in the control group (ED_{10}). The route-specific carcinogenic toxicity constants are calculated as follows:

water: $w_{tc} = 2/70 \times ED_{10}$

soil: $s_{tc} = 0.0001/70 \times ED_{10}$

air: $a_{tc} = 20/70 \times ED_{10}$

The constants in all of the above equations reflect reference human values (70 kilograms body weight, 20 m^3/day inhalation rate, 2 l/day water ingestion rate, and 100 mg/day soil ingestion rate) used to convert dose units into ambient concentration units.

Several other factors are considered subjectively in determining the indicator chemicals, in addition to the indicator score: persistence of the chemical, weight of evidence for carcinogenicity, water solubility, vapor pressure, Henry's constant, and organic carbon partition coefficient.

SUPERFUND PUBLIC HEALTH EVALUATION (SPHE) SYSTEM (Concluded)

SIMILARITIES TO HRS: The only similarities between the HRS and the SPHE systems are that both address noncarcinogenic chronic effects and persistence on a route-specific (or pathway-specific) basis.

DIFFERENCES FROM HRS: There are numerous differences between the HRS and the SPHE system. First, the HRS toxicity score depends heavily on the relative acute toxicity of the chemical in question. The SPHE system does not address acute toxicity. Second, the SPHE system considers carcinogenic effects, while the HRS does not. Third, the SPHE system indirectly considers the mobility of the chemicals, in terms of their basic chemical characteristics. No consideration is given to contaminant mobility in the HRS. Finally, the SPHE system includes the measured or estimated chemical concentration at the site in question in determining the indicator score. The HRS uses concentration data only to establish observed releases.

CONCLUSIONS: The approach to deriving toxicity constants in the SPHE should be evaluated in terms of possible adaptation for use in the HRS. The remaining aspects of the SPHE are either not sufficiently defined (e.g., use of persistence and mobility information) to be employed in the HRS or require data beyond the scope of a current site inspection.

REFERENCES: ICF Incorporated, Superfund Public Health Evaluation Manual, (Draft), ICF Incorporated, Washington, DC, October 1, 1985.

C.2 Other Systems Identified

This section presents summaries of two reports that reviewed chemical hazard ranking systems. The first report reviewed 23 systems, while the second reviewed 34 systems. Five of the systems reviewed are included in both sets of reviews.

REVIEW OF 23 CHEMICAL HAZARD RANKING SCHEMES

SYSTEM: Twenty-three schemes for ranking the hazard associated with wastes and waste constituents are reviewed in the indicated reference (see Table C-1 for a list of these 23 schemes). (Note that 34 other systems which were developed more than 10 years ago were also briefly reviewed in the indicated reference. Most of these schemes were developed for use as screening tools for prioritizing chemicals for further study. They were not meant to rank the relative hazard of chemicals. Most of these early systems were considered in the development of the current systems included in the review. Consequently, they are not considered further in this summary.)

USER: All but the last two systems listed in Table C-1 are used by or proposed for use by a variety of Federal agencies, States, and foreign governments. These last two systems are early systems that are no longer being used.

DEVELOPER: These systems have been developed by a variety of Federal agencies, States, foreign governments, trade associations, and private organizations.

USE/STATUS All but the last two systems in Table C-1 have been developed within the last 10 years and are either currently being used or have been proposed for use in calculating the hazard (i.e., relative risk) associated with waste streams and waste constituents.

GENERAL DESCRIPTION: The 23 hazard ranking schemes fall into three categories: classification schemes, risk analysis models, and numerical schemes. Thirteen of the hazard ranking schemes are classification schemes, 4 are models, and 6 are numerical schemes. The classification schemes use specific technical criteria (e.g., LD_{50} of less than X) to

TABLE C-1

LIST OF 23 CHEMICAL HAZARD RANKING SYSTEMS
INCLUDED IN ENVIRON CORPORATION REVIEW

EPA HAZARDOUS WASTE/CHEMICAL RANKING SCHEMES

- Selected Criteria Processing
- Assessment of Air Emissions from Hazardous Waste Treatment, Storage and Disposal Facilities
- RCRA Risk-Cost Analysis Model
- Toxicity Scoring System Using RTECS Data Base
- Integrated Environment Management Program
- OTS Chemical Scoring System

OTHER FEDERAL SCHEMES

- U.S. Army Hazard Multi-Media Estimating and Ranking Scheme

STATE HAZARDOUS WASTE RANKING SCHEMES

- Alaska
- California
- Louisiana
- Maryland
- Michigan
- Rhode Island
- Washington

FOREIGN RANKING SCHEMES

- EEC Ranking Algorithm for Water Pollutants

OTHER RANKING SCHEMES

- Chemical Manufacturers Association
- Dow Chemical
- Soap & Detergent Association
- American Paper Institute and National Forest Products Association
- National Paint and Coating Association
- Weyerhauser Company
- Booz-Allen Barring Model
- PHL Model

GENERAL DESCRIPTION: categorize wastes into specific hazard classes such as low, medium, and high hazard. The modeling schemes are basically risk analysis models, employing complex submodels, and have to be run on a computer. The numerical schemes use numerical scales to assign values to factors based on specified hazard characteristics of the waste (e.g., acute toxicity, persistence, carcinogenicity). The value for each hazard characteristic is weighted and combined to obtain a single numerical hazard value for the waste or waste constituent.

SIMILARITIES TO HRS: Both the numerical schemes and classification schemes represent alternatives to the Sax rating scheme used to assign values to the HRS toxicity factor.

DIFFERENCES FROM HRS: The modeling schemes are not comparable to the HRS toxicity factor (e.g., see the discussion of the RCRA Risk-Cost Policy Model in Appendix B).

CONCLUSIONS: The various numerical and classification schemes all need to be evaluated further to assess their applicability to the HRS. One of the major concerns with these schemes is the availability of the data required by them to rank the large number of substances that are hazardous under CERCLA.

REFERENCES: Environ Corporation, Review and Analysis of Hazard Ranking Schemes, Final Report, May 11, 1984.

REVIEW OF 34 SCORING SYSTEMS FOR CHEMICAL HAZARD ASSESSMENT

SYSTEM:	Thirty-four scoring systems for chemical hazard assessment are identified and reviewed in the indicated reference (see Table C-2 for a list of these 34 schemes).
USER:	These systems are used by a variety of Federal agencies, quasi-governmental organizations (e.g., National Cancer Institute, National Academy of Science), States, foreign governments, and industries (see Table C-2).
DEVELOPER:	These systems have been developed by a variety of Federal agencies, quasi-governmental organizations, States, and private organizations (see Table C-2).
USE/STATUS:	The scoring systems reviewed are intended to be used for one of two purposes: to select or prioritize chemicals for testing or to select or prioritize chemicals for regulation or control. The scoring systems reviewed have been used to score pesticides, new chemicals, food contaminants, synthetic organic chemicals, and hazardous wastes. Some of the scoring systems were also developed to deal with specific environmental compartments such as the atmosphere or aquatic life. Some were developed to assess risk to specific populations such as employees of selected industries, users of consumer products, or residents near a landfill. The various scoring systems have been used to score anywhere from 6 to 28,000 chemicals; however, only 8 systems have been applied to over 500 chemicals.
GENERAL DESCRIPTION:	For each of the 34 scoring systems, the review article identifies why the system was developed, who developed the system, who the system was developed for, the factors used in the scoring, the algorithms by which scores are combined, and the universe of substances to which they have been applied.

TABLE C-2

LIST OF 34 IDENTIFIED SCORING SYSTEMS FOR CHEMICAL HAZARD ASSESSMENT

System	User	Developer
Pesticide Manufacturing Air Prioritization	EPA/IERL	Monsanto
Sequential Testing for Toxicity Classification	Not identified	Eastman Kodak Co.
Index of Exposure	EPA	Auerbach Associates
Chemical Hazard Ranking System	CPSC	ITT Research Institute
System for Evaluation of the Hazards of Bulk Water Transport of Industrial Chemicals	U.S. Coast Guard	NAS
Barring Model	Not identified	Booz-Allen Applied Research
Select Organic Compounds Hazardous to Environment	National Science Foundation	Stanford Research Institute
Ranking Algorithm for EEC Water Pollution	EEC	Stanford Research Institute
Setting Priorities for R&D on Army Chemicals	USAMRDC, Fort Derrick	Stanford Research Institute
System for Rapid Ranking of Environmental Pollutants	EPA/ORD	Stanford Research Institute
Estimating Hazard of Chemical Substances to Aquatic Life	Not identified	ASTM, Committee D-19
Estimation of Toxic Hazard--A Decision Tree	Industry	Flavor and Extract Manufacturer's Associates

TABLE C-2 (Continued)

System	User	Developer
TSCA-ITC Scoring System Workshop	EPA/ITC	Enviro Control, Inc.
Action Alert System	EPA/OWRS	Arthur D. Little, Inc.
Scoring of Organic Pollutants	EPA/OAQPS	The MITRE Corporation
Ranking of Environmental Contaminants for Bioassay Priority	National Cancer Institute	Stanford Research Institute
PHL Model	Not identified	Pavoni, Hagerty, and Lee
Hazard Evaluation Procedure for Potentially Toxic Chemicals	UNEP	Monitoring and Assessment Research Center
Selection of Chemicals for Inclusion in a Trend Monitoring	Federal Republic of Germany	The MITRE Corporation
RCRA Risk-Cost Policy Model	EPA/OSW	ICF Inc., Clement Associates, SCS Engineers
ITC Scoring for Biological Effects	EPA/ITC	Clement Associates
Ranking of Food Contaminants	OTA	Clement Associates
Rapid Screening and Identification of Airborne Carcinogens	State of California	SAI
Michigan Critical Materials Register	Michigan Department of Natural Resources	State of Michigan

TABLE C-2 (Concluded)

System	User	Developer
National Occupational Hazard Survey	NIOSH	NIOSH
Assessment of Oncogenic Potential	Not identified	Hooker Chemical
ITC Scoring for Exposure Order of Commercial Chemicals on NIOSH Suspected Carcinogens List	EPA/ITC Not identified	Clement Associates EPA/OPTS
Identification of High-Risk Occupational Groups and Industrial Processes	NIOSH DCCP/NCI	Tracor Jitco
OECD Ecotoxicology Testing Scheme	EPA/OPTS	Battelle
Chemical Scoring System Development	EPA/OPTS	Oak Ridge National Lab
Environmental Scoring of Chemicals	EPA/OPTS	Oak Ridge National Lab
Ranking Animal Carcinogens	Not identified	R. Squire
Hazard Assessment by a Qualitative System	French Ministere de l'Environment	Association Chimie et Ecologie

Source: Hushon and Kornreich, 1984.

REVIEW OF 34 SCORING SYSTEMS FOR CHEMICAL HAZARD ASSESSMENT
(Continued)

SIMILARITIES:

Based on the review, only two of the scoring systems appear to have any relevance to the HRS. The systems are the following:

- Barring Model
- PHL Model

Each is used to estimate the hazard of chemicals disposed in waste sites. As such they may provide alternatives to the Sax rating scheme used in the HRS toxicity factor.

DIFFERENCES FROM HRS:

Most of the 34 scoring systems are not comparable to the HRS. Sixteen are meant as screening tools for use in prioritizing chemicals, especially new chemicals or suspected carcinogens, for more intensive scientific study. These systems are not meant to rank the relative hazard of chemicals for use in regulatory programs.

Fifteen of the scoring systems are meant to identify high risk chemicals based on exposure by selected populations. As such these scoring systems focus on many factors not relevant to the HRS such as chemical production volume, fraction of production lost, use patterns, production emission sources and rates, and population exposed through production or use.

One scoring system is designed to test how well aquatic tests predict hazard potential.

CONCLUSIONS:

Only two of the scoring systems identified in the review need to be evaluated further to assess their applicability to the HRS. These are the Barring Model and the PHL Model. They are reviewed in Section C.1 of Appendix C.

REVIEW OF 34 SCORING SYSTEMS FOR CHEMICAL HAZARD ASSESSMENT
(Concluded)

REFERENCES: Hushon, Judith and Mary Kornreich, Scoring Systems for Hazard Assessment, Hazard Assessment of Chemicals: Current Developments, Volume 3, pp. 63-109, Academic Press, Inc., 1984.