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Energy Division

EMERGENCY RESPONSE CONCEPT PLAN FOR TOOELE ARMY DEPOT AND VICINITY

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ACRONYMS AND ABBREVIATIONS

ACh	acetylcholine, a neurotransmitter
AChE	acetylcholinesterase, an enzyme that prevents the accumulation in the body of acetylcholine
AMC	U.S. Army Materiel Command
BAL	British anti-lewisite
°C	degrees Centigrade
CAIRA	chemical accident/incident response and assistance
CAMDS	Chemical Agent Munition Destruction System
CAS	Chemical Abstracts Service
CEHIC	Center for Environmental Health and Injury Control, U. S. Department of Health and Human Services
cm	centimeter
CONUS	the 48 contiguous states of the continental United States
CSPD	Chemical Stockpile Disposal Program
CY	calendar year
D2PC	U.S. Army atmospheric dispersion code developed by Whitacre, et al. (1986)
DA	U.S. Department of the Army
DHHS	U.S. Department of Health and Human Services
DUN	dunnage incinerator
EBS	Emergency Broadcasting System
ECR	explosive containment room
ECV	explosive containment vestibule
EOC	emergency operations center
EPA	U.S. Environmental Protection Agency
EPZ	emergency planning zone
ERCP	Emergency Response Concept Plan (Jacobs Engineering Group, Inc., and Schneider EC Planning and Management Services 1987)
°F	degrees Fahrenheit
FEMA	Federal Emergency Management Agency
FIREX	military exercise recently conducted at TEAD

FPEIS	Final Programmatic Environmental Impact Statement for the Chemical Stockpile Disposal Program (U.S. Department of the Army 1988)
FY	fiscal year
g	gram
GA	ethyl-N, N-dimethyl phosphoramidocyanidate; "Tabun"; a nerve agent
GB	isopropyl methyl phosphonoflouridate; "Sarin"; a nerve agent
H	bis (2-chloroethyl) sulfide; a vesicant or blister agent
HD	a purified version of H
Hg	mecury
HT	a vesicant or blister agent consisting of 60% HD and 40% T
IEMIS	Integrated Emergency Management Information System
in	inch
IRZ	immediate response zone
kg	kilogram
km	kilometer
L	dichloro(2-chloro-vinyl)arsine; "Lewisite"; a vesicant or blister agent
lb	pound
m	meter
m/s	meters per second
MDB	munitions demolition building
MEOWS	maximum envelopes of water (concept used in emergency planning for hurricanes)
MHI	munitions handling igloo
min	minute
ML	most likely meteorological conditions
mm	millimeter
MOU	memorandum of understanding
MPB	munitions processing bay
MPF	metal parts furnace

MSL	mean sea level
ND	no deaths (the distance beyond which fatalities would not be expected to occur)
ORNL	Oak Ridge National Laboratory
PAZ	protective action zone
PM Cml Demil	Program Manager for Chemical Demilitarization
PZ	precautionary zone
REP	radiological emergency planning (concept used in emergency planning for fixed site nuclear power facilities
SCBA	self-contained breathing apparatus
SOP	standard operating procedure
T	(bis[2(2-chloroethylthio)ethyl]ether, an agent combined with H to make vesicant or blister agent HT
TEAD	Tooele Army Depot
TEAD-N	Tooele Army Depot, north area
TEAD-S	Tooele Army Depot, south area
TMI	Three-Mile Island nuclear plant, Pennsylvania
U.K.	United Kingdom
USANCA	U.S. Army Nuclear and Chemical Agency
USNRC	U.S. Nuclear Regulatory Commission
VS	very stable meteorological conditions
VX	o-ethyl-S-(2-diisopropylaminoethyl)methyl phosphonothiolate; a nerve agent

ABSTRACT

The continued storage and disposal of the United States' unitary chemical stockpile, including that portion stored at Tooele Army Depot (TEAD) near Tooele, Utah, have the potential for accidental releases that could escape installation boundaries and pose a threat to civilian populations. The U.S. Army, in conjunction with the Federal Emergency Management Agency and other federal agencies, is committed to implement an emergency preparedness program that will significantly reduce the probability of adverse effects from such releases. This concept plan, which is but a part of a comprehensive ongoing effort, provides a framework for initiating such a program for the TEAD stockpile.

This report develops information and methodologies that bear on two major decisions for such a program -- determining emergency planning zones and selecting protective action strategies. These decisions are based on the hazards posed by the TEAD stockpile and its disposal. These hazards, in turn, are based largely on the distribution of potential accidental releases associated with interim storage and disposal activities and associated external events (e.g., earthquakes and airplane crashes), the distribution of natural features that can affect an agent release (topographical features and meteorological characteristics), and the distribution of people and resources (e.g., homes, schools, and hospitals) potentially affected by an accidental release.

A conceptually simple methodology for determining emergency planning zone (EPZ) boundaries is developed and applied to the TEAD stockpile, and a recommended EPZ and set of boundaries are identified. The EPZ consists of two zones, an immediate response zone (IRZ) with a radius of approximately 15 km from the storage area and proposed disposal site and a protective action zone (PAZ) with a radius of approximately 50 km from those locations. Actual boundaries are based on topographic features in the area (e.g., Oquirrh Mountains, South Mountain, Rush Valley, Tooele Valley, and Cedar Valley) which would constrain the dispersion of an accidental release and political boundaries or landmarks with which the local population is familiar.

The report identifies the advantages and disadvantages of six categories of protective actions (i.e., evacuation, in-place sheltering, respiratory protection, protective clothing, prophylactic drugs, and antidotes) and various options among these categories. Potentially suitable options for the IRZ and PAZ general publics and institutional populations are identified, and preliminary recommendations are made. For the general population in the IRZ, the recommended option is to evacuate with respiratory protection. For impaired persons in the IRZ, positive pressurization of a "safe" room in a house or building is recommended. For the PAZ, evacuation is recommended for all persons.

The viability of the recommended EPZ and the effectiveness of the recommended protective actions depend on the adoption and implementation of appropriate standards for command and control decisions and for alert and notification systems. Given the possibility of rapid onset of accidents at TEAD and the proximity of civilian populations in the IRZ, an overall command and control structure must be able to provide a decision on warning and protective actions in less than ten minutes from accident detection. Somewhat more time is available for the PAZ.

1.0 INTRODUCTION

1.1 PURPOSE OF THE CONCEPT PLAN

This concept plan was developed to help initiate enhanced emergency preparedness for continued storage of the stockpile and the Chemical Stockpile Disposal Program (CSDP) at Tooele Army Depot (TEAD). The chief purpose of this document is to act as a preliminary aid to decision-making regarding the implementation of enhanced emergency planning and preparedness. The Army recognizes that there is no set plan that is applicable to all program sites. Variation in population distribution, political boundaries, topographical features, risk and accident potential all create a situation in which options and alternatives are both needed and available. It is the responsibility of state and local governments to shape the emergency preparedness mitigation program. The Army can provide resources and expertise, but cannot impose an arbitrary program on the local communities.

To achieve that purpose the major thrust of this document is to identify major decisions that need to be made and to provide preliminary data and analyses that can help make informed decisions. Where feasible, it identifies decision options and presents the advantages and disadvantages regarding each option. Where information is compelling, recommendations are offered, but in the spirit that other outcomes will not be automatically dismissed or ignored.

The two major decisions that are addressed in this concept plan are defining the boundaries of emergency planning zones and selecting protective action strategies to protect human health and safety. The definition of planning zones follows the basic concept set forth in the *Emergency Response Concept Plan (ERCP)* [Report SAPEO-CDE-IS-87007, prepared by Jacobs Engineering Group, Inc. and Schneider EC Planning and Management Services for the Program Manager for Chemical Demilitarization (PM Cml Demil) in 1987] of an inner immediate response zone and a larger protective action zone; there is also an outer zone, termed the precautionary zone in the *ERCP* where ample time should be available to implement appropriate protective action without significant prior planning. The protective action strategies and decisions have been discussed in two preliminary technical reports (Chester, 1988; Sorensen, 1988). Additional work is underway expanding on the analysis of protective actions as well as on other matters that will have a bearing on the technical basis for planning. As these materials are completed, they will be made available to federal, state, and local officials engaged in the emergency planning process.

1.2 BACKGROUND AND OVERVIEW OF THE EMERGENCY PLANNING AND PREPAREDNESS PROGRAM

This program is outlined in the CSDP Final Programmatic Environmental Impact Statement (FPEIS, U.S. Army 1988). As defined in the FPEIS, major activities to be undertaken include:

- development of a new command/control, communication and decision-making system,
- development of an improved technical planning basis,
- development of improved emergency operating procedures,
- development of improved exercise design and evaluation
- conducting emergency exercises,
- establishment of an oversight review board,
- coordination with appropriate state and federal agencies, and
- development of a program to implement other emergency preparedness improvements.

This program is to be implemented at the eight storage/disposal sites to reduce adverse health and environmental effects in the event of an accidental release of chemical agent. The program will be based on the *ERCP*. The *ERCP* identified options for improving preparedness for accidents under all programmatic disposal alternatives. The programmatic record of decision, issued by Under Secretary of the Army James R. Ambrose on 23 February 1988, specified that onsite disposal was the alternative to be pursued at each site. This site-specific concept plan addresses the framework for improving emergency preparedness for storage and disposal activities at TEAD in a much more specific and focused manner than was possible in the *ERCP*.

After the programmatic record of decision was rendered, the Department of the Army (DA) and the Federal Emergency Management Agency (FEMA) initiated discussions regarding the development of a Memorandum of Understanding whose purpose was to establish a framework of cooperation to identify their agencies' respective roles and responsibilities for emergency response preparedness involving the storage and ultimate disposal of chemical warfare materials and to establish joint program efforts in emergency response planning, training, and information exchange. This MOU also identified roles and responsibilities for the Department of Health and Human Services (DHHS) and the Environmental Protection Agency (EPA) and set up a FEMA/DA Joint Steering Committee to review the status of joint programs, discuss and resolve issues, consult on major policy issues, and provide the necessary direction to meet the Army's overall program goals. The MOU was signed in August 1988.

With the assistance of FEMA, other federal agencies and contractor organizations, the Army is in the process of upgrading the off-site or civilian emergency plans and procedures at each of the sites, analyzing training needs, evaluating communication system needs, and investigating warning system needs. These activities, however, are fragments of a larger picture. The overall emergency planning and preparedness program for the stockpile and its disposal is comprehensive and multi-faceted. As shown in Table. 1.1, the overall program involves the efforts of many parties (e.g., various parts of the Army, including the installations and contractors, other federal agencies such as the Federal Emergency Management Agency, and the affected state and local jurisdictions).

Although some of the activities can be and are being pursued simultaneously, there are interdependencies among many of the activities that dictate a temporal flow to the program, as depicted in Fig. 1.1. Phase I of the program (scheduled to occur between January 1987 and June 1990) is to

Table 1.1 CSDP Emergency Planning and Preparedness Program activities and participating organizations

Activity	Organizations[a]											
	DA	FEMA	PM Cml Demil	CEHIC/ DHHS	AMC	USANCA	Installation	State gov't	Local gov't	ORNL	Schneider	Undeter- mined
Develop/ conduct medical training	C[b]			R[c]				C	C			
Training needs analysis			R								C	
Prepare commun. concept study			R								C	
Prepare public alerting concept study			R								C	
Develop interim plans (on- and off-post)			R				C	C	C		C	
Technical support studies		R	R							C		

Table 1.1 (continued)

Organizations

Activity	DA	FEMA	PM Cml Dmil	CEHIC/ DHHS	AMC	USANCA	Installation	State gov't	Local gov't	ORNL	Schneider	Undetermined
Develop standards and criteria		R								C	C	
Revise CAIRA manual						R						
Develop site-specific concept plans		R	R							C		
Evaluate site-specific protective action strategies	R	R								C		
Provide technical assistance and planning support		R										C
Develop/revise comprehensive plans							R	R	R			C
Develop public affairs program		R						C	C			C

Table 1.1 (continued)

Organizations

Activity	DA	FEMA	PM Cml Demil	CEHIC/ DHHS	AMC	USANCA	Installation	State gov't	Local gov't	ORNL	Schneider	Undetermined
Implement public affairs program		R						C	C			C
Prepare equipment acquisition plan					R					C	C	
Determine site equipment requirements	R	C			C		C	C	C	C		C
Finalize equipment requirements					R							C
Procure, install, and test equipment					R							C
Develop training program	C	R										C
Implement training program		R										C

Table 1.1 (continued)

Organizations

Activity	DA	FEMA	PM Cml Demil	CEHIC/ DHHS	AMC	USANCA	Installation	State gov't	Local gov't	ORNL	Schneider	Undetermined
Develop exercise program		R										C
Conduct initial exercises		R										C
Maintain plans (on- and off-post							R	R	R			C
Maintain public affairs program		R										C
Maintain equipment and systems							R	R	R			C
Maintain training and exercise program		R					C	C	C			C

[a]DA = U.S. Department of the Army; FEMA = Federal Emergency Management Agency; PM Cml Demil = Program Manager for Chemical Demilitarization; CEHIC/DHHS = Center for Environmental Health and Injury Control/U.S. Department of Health and Human Services; AMC = U.S. Army Materiel Command; USANCA = U.S. Army Nuclear and Chemical Agency; ORNL = Oak Ridge National Laboratory

[b]C = contributing

[c]R = responsible

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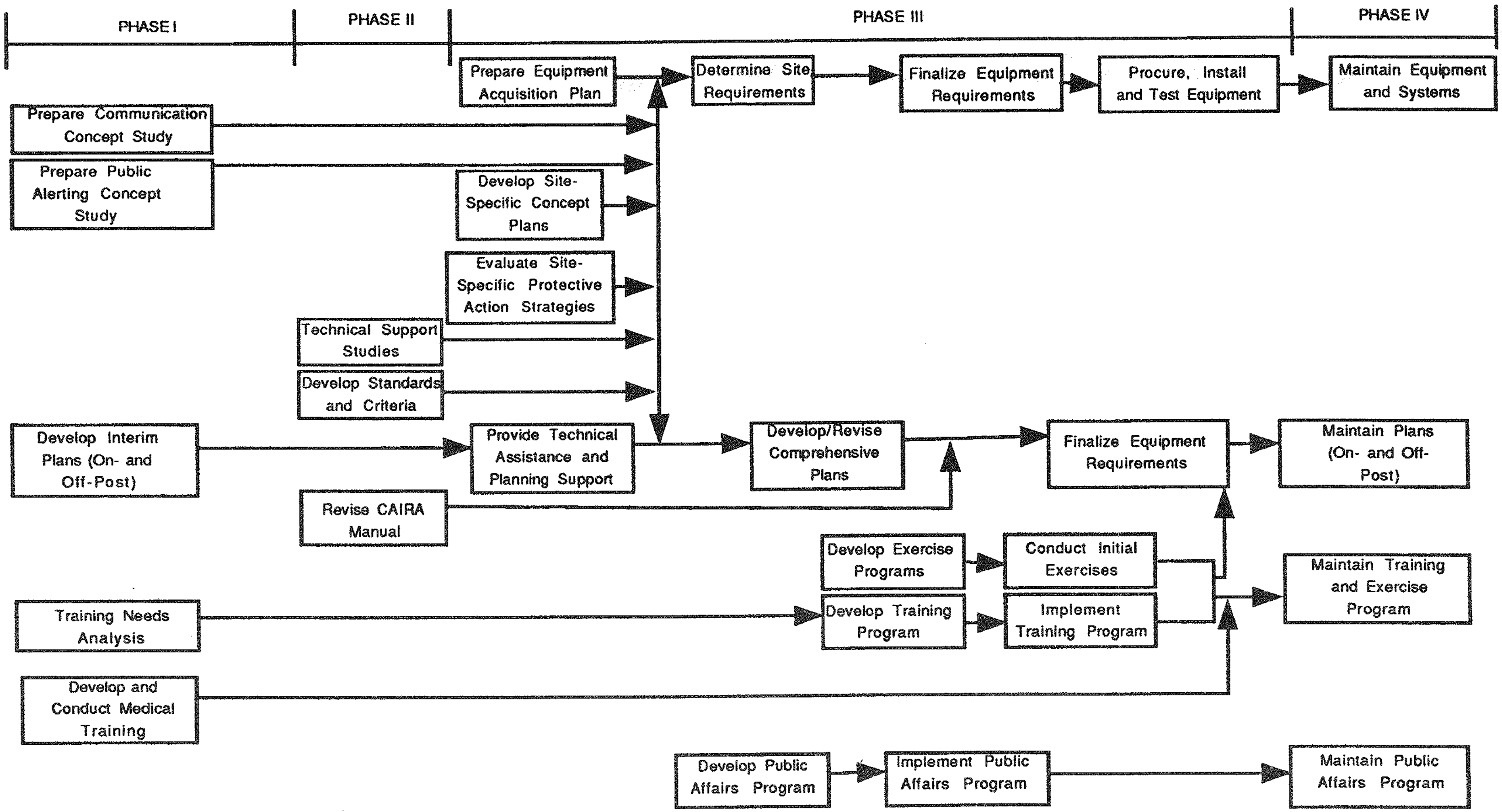

Fig. 1.1. CSDP Emergency Planning and Preparedness Program Activities.

provide an interim upgrade of off-post emergency planning using existing community resources and to develop and conduct chemical accident medical training courses for emergency workers; Phase I also includes studies analyzing equipment needs for communications and public alerting, and an initial analysis of program training needs. Phase II of the program (scheduled to occur between April 1988 and January 1991) includes the preparation of various technical studies to support local decision making and form the basis for program guidance and the definition of standards and criteria to be used to determine the adequacy of comprehensive emergency plans and preparedness for the program; ongoing and scheduled technical studies and the dates by which results are anticipated to be available to emergency planning program participants are shown in Table 1.2. Phase III of the program (scheduled for April 1988 through June 1993) constitutes the implementation of the program. It includes the preparation of site-specific concept plans; the determination of planning, equipment and training needs required to satisfy the standards and criteria established during Phase II; the acquisition, installation and testing of equipment and training of emergency response organizations and personnel in its use; and the implementation of comprehensive planning, training, and exercise programs. Phase IV, comprised of maintenance and support of the major preparedness programs, is planned to start in June 1991 and last until the lethal agent stockpile is eliminated (scheduled for April 1997).

1.3 OBJECTIVES OF EMERGENCY PREPAREDNESS

Before presenting any concepts, it is important to reflect upon what objectives should be used to guide the enhancements. Three programs objectives are important to the program. These include

- loss reduction,
- community participation, and
- functional equivalency.

Loss reduction, as measured primarily by avoidance of fatalities given an accidental release of chemical agent, is obviously the most important objective of the concept plan and implementation process. Thus, whenever feasible, decisions should be driven by concern for public safety. A second goal is to obtain a preparedness strategy and capability that is publicly acceptable and, thus, workable. Thus, the goal of community participation maintains that the citizens affected by the emergency preparedness mitigation need to become part of the planning process. Finally, since there are a total of 8 storage/disposal sites, the allocation of resources cannot be biased toward any given site. Each site, however, has different needs and may opt for different approaches. It is therefore important that each site receives enhancements that are more or less equivalent from a functional perspective, or are not denied resources that are functionally equivalent. The equitable distribution of resources should also contribute to public acceptance of the emergency preparedness program.

Table 1.2 Technical Support Studies

Study	Status	Results Expected
Accident Assessment	In progress	FY 1989
Protective Action Effectiveness	In progress	FY 1990
Public Education/Risk Communication Strategy Plan	In progress	FY 1990
Decision Making System	In progress	FY 1990
Atmospheric Dispersion Model Review	In progress	FY 1990
Reentry Planning	In progress	FY 1990
Review of Protective Equipment for Civilian Workers	Scheduled	FY 1990
Public Education Program Technical Support	Scheduled	FY 1990
Develop Warning System Evaluation Methodology	Scheduled	FY 1990
Protocols for Biological Monitoring for	Scheduled	FY 1990
Evacuation Studies	Scheduled	FY 1990-91
Evaluation of Site-Specific Protective Action Strategies[1]	Scheduled	FY 1990-91
Development of a Computer-Based Emergency Information System	Scheduled	FY 1990-91
Agent Contamination of Porous Media	Scheduled	FY 1991
Agent Contamination of Agricultural Resources	Scheduled	FY 1991

[1] This is shown as a separate activity in a draft management plan for the CSDP Emergency Planning and Preparedness Program.

1.4 ALTERNATIVE LEVELS OF ENHANCED PREPAREDNESS

The current preparedness plans for chemical weapons accidents at TEAD are described in *Tooele Army Depot Disaster Control Plan Annex C/Chemical Accident Incident Control Plan* (Tooele Army Depot, 1985) and *Draft Tooele County Emergency Operations Plan* (Tooele County, 1988). Enhanced planning can be defined in a great number of ways. One means of viewing enhancement is to define three different preparedness levels:

- minimum,
- current state-of-the-art practice, and
- maximum protection.

While no functional criteria for defining these three levels have been specified, they can be qualitatively defined as follows. The minimum effort would be to upgrade preparedness by making the most of available resources within each community and installation. Limited improvements in equipment would be feasible where it is deemed that equipment is obsolete.

The current state-of-the-art practice would involve implementing a preparedness level similar to that found for commercial nuclear power plants around the country. The basis for this level of preparedness is defined in NUREG 0654/FEMA REP 1 (USNRC, 1980).

The maximum protection level would involve developing a system which would prevent as much loss as possible under all envisionable, but credible, accident scenarios. This would likely have a very high price tag (and may, in fact, assume unlimited resources) and may be very intrusive on a community's everyday functioning.

1.5 OVERVIEW OF THE PLAN

Section 2 of this plan presents information on the distribution of credible accidents that could occur at TEAD. Accidents are described with respect to cause, type of release, duration of release, and downwind hazard consequences. From the distribution, planning basis accidents are developed. These represent accident categories that describe classes of events that are similar in nature.

Section 3 of the plan examines characteristics of the site. Relevant characteristics include site topography, local meteorological conditions, population distributions, and special or institutional populations such as schools and hospitals.

Section 4 addresses the delineation of emergency planning zones, including the immediate response, protective action, and precautionary zones. A base case is developed for each zone along with a rationale for the boundaries. Alternative boundaries are also presented along with arguments for the deviation from the base case. The final determination of emergency planning zone boundaries will be made collectively by affected local governments, state government, the Department of the Army, and the Federal Emergency Management Agency.

Section 5 identifies protective action options for the population surrounding the proposed disposal site. The analysis defines what are considered to be legitimate options for varying distances from the facility or potential accident site. Protective actions for the general population are differentiated from those applicable to institutional populations.

The last section defines the direction for the program. Discussed in turn are program standards, major uncertainties, program decisions, and program schedule. The timing of the program is intimately tied to decision outcomes. Although estimates can be made regarding the timing of certain activities (e.g., the timing of Phases I through IV noted above), until decisions are actually made, the actual schedule is unknown.

Finally, it should be pointed out that this concept plan is evolving. It does not cast information in stone, nor render options monolithic. It is a starting point for a set of interactions among officials, concerned citizens, and experts to enhance the actual and perceived safety of residents surrounding the storage and disposal sites.

2.0 PLANNING-BASIS ACCIDENT CATEGORIES

The selection of protective actions to be implemented in the TEAD area should be based on the hazards posed by the TEAD stockpile and its disposal. These hazards, in turn, are based largely on characteristics of the stockpile, the distribution of potential accidental releases associated with interim storage and disposal activities and associated external events (e.g., earthquake, airplane crash), the distribution of natural features that can affect an agent release (e.g., topographical features and meteorological characteristics), and the distribution of people and resources (e.g., homes, schools, and hospitals) potentially affected by an accidental release. After describing the stockpile at TEAD and the range of potential accidental releases, this section classifies those accidental releases into useful planning categories and defines planning-basis accident categories for the TEAD area.

2.1 STOCKPILE PROFILE

2.1.1 Chemical Agents at TEAD

The chemical agents to be destroyed at TEAD include both nerve agents and vesicant or blister agents. All are hazardous to humans; the type and extent of hazard is determined by the physical and toxicological characteristics of the agent and the extent, route, and duration of the exposure. Table 2.1 lists some of the physical and chemical characteristics of the agents. The following discussion summarizes a detailed account of human health effects (i.e., acute and chronic exposure toxicity) of the chemical agents found in Appendix B of the FPEIS (U. S. Army 1988).

Three nerve agents are stored at TEAD: (1) GA, which is also called "Tabun," (2) GB, which is also called "Sarin," and (3) VX/ These compounds are all organophosphorous esters that directly affect the nervous system. Usually odorless, colorless, and tasteless, the nerve agents are highly toxic in both liquid and vapor forms. Their mechanism of action involves the inhibition of acetylcholinesterase (AChE), and enzyme that prevents the accumulation of the neurotransmitter acetylcholine (ACh). After exposure to nerve agent, AChE is inhibited and ACh accumulates; at high doses, the results are convulsions and death due to paralysis of the respiratory system. Death from nerve agents can occur quickly, often within ten minutes of absorption of the fatal dose. Sublethal effects of acute exposures include effects on the skeletal muscles (uncoordinated motions followed by paralysis), effects on the portion of the nervous system which controls smooth muscles and glandular secretions (i.e., pinpoint pupils, copious nasal and respiratory secretion, bronchoconstriction, vomiting, and diarrhea), and effects on the central nervous system (thought disturbances and convulsions). VX is the most persistent of the nerve agents and is the least volatile. GB is the most volatile and would pose the greatest inhalation threat in an accidental release. In relative terms, VX is more toxic than GB, which, in turn, is more toxic than GA.

The vesicant (or blister) agents stored at TEAD include the mustard-derived agents H, HD, HT, as well as lewisite (L). The major toxic chemical [bid(2-chloroethyl)sulfide] in both H and HD is also known as mustard gas, sulfur mustard, or mustard. H is sulfur mustard which contains about 30% sulfur impurities. HD is the purified chemical from which the impurities have

Table 2.1 Characteristics of chemical agents at TEAD

Agent	Common name	CAS No.[a]	Chemical name	Chemical formula	Vapor pressure (at 25°C)	Liquid density (at 25°C)	Freezing point	Color	Mode of action
Nerve									
GA	Tabun	77-81-6	Ethyl-N, N-dimethyl phosphoramidocyanidate	Empirical: $C_5H_{11}N_2O_2P$	0.07mm Hg	1.073 g/cm^3	-50°C	Colorless to brown	Nervous system poison
GB	Sarin	108-44-8	Isopropyl methyl phosphonofluoridate	$C_4H_{10}FO_2P$	2.9mm Hg	1.089 g/cm^3	-56°C	Clear to straw to amber	Nervous system poison
VX		50782-69-9	*o*-ethyl-S-(2-diisopropylaminoethyl) methyl phosphonothiolate	$C_{11}H_{26}NO_2PS$	0.0007mm Hg	1.008 g/cm^3	Below -51°C	Clear to straw	Nervous system poison
Vesicant									
H, HD	Mustard	505-60-2	bis(2-chloroethyl) sulfide	$C_4H_8Cl_2S$	0.08mm Hg[e](H) 0.11mm Hg (HD)	1.27 g/cm^3	8-12°C(H) 14°C(HD)	Amber to dark brown	Blistering of exposed tissue
HT	Mustard		60% HD and 40% T[b]		0.104mm Hg	1.27 g/cm^3	1°C	Amber to dark brown	Blistering of exposed tissue
L	Lewisite	541-25-3	Dichloro(2-chlorovinyl) arsine	$C_2H_2AsCl_3$	0.58mm Hg	1.89 g/cm^{3c}	-18°C[d]	Amber to dark brown to black	Blistering of exposed tissue

[a]Chemical Abstracts Service Number.
[b]Agent T is Bis[2(2-chloroethyl-thio)ethyl]ester; it is CAS No. 63918-89-8.
[c]At 20°C.
[d]Varies +0.1°C, depending on parity and isomers present.
[e]Varies with purity of sample.

been removed by washing and distillation. HT is an approximate 60%/40% blend of agents HD and T (bis[2(2-chloroethylthio)ethyl]ether), developed for use as a lethal vesicant mixture. The addition of T to HD creates a form of mustard which has a longer duration of effectiveness and a lower freezing point than HD. Lewisite is an arsenical vesicant of the class termed organic dichloroarsines. This agent is far more volatile than HD and can be used as a "moderate irritant" vapor over greater distances.

The principal health effect of vesicant exposure is blistering of exposed tissues, potentially causing severe skin blisters, injuries to the eyes, and damage to the respiratory tract by inhalation of vapors. Because of its chemical properties, mustard agent can react with a variety of tissue constituents including nucleic acids, the genetic material of the cell. Biological evidence indicates that mustard exposure can result in carcinogenesis. In order of inhalation toxicity, HT is more toxic than HD, HD is more toxic than H, and H is more toxic than L. Mustard is extremely persistent when isolated from sun, wind, and rain; it can still be found in European trench areas sealed during World War I. Mustard normally hydrolyzes in the open over a period of several days; temperature is a major factor in natural deterioration.

2.1.2 Chemical Munitions at TEAD

TEAD has the largest and most heterogeneous inventory of all CONUS installations. Although the size of the inventory is important in the context of the probability of an agent release, the stockpile mix also has important implications for emergency planning - the more heterogeneous the mix, the larger the variety of potential releases to plan for. The specific composition of the TEAD stockpile in terms of agent and munition mix is shown in Table 2.2.

Table 2.2 TEAD Stockpile

Munition or container	Agent						
	H	HD	HT	L	GB	GA	VX
105-mm projectile					X		
155-mm projectile	X	X			X		X
4.2-in. mortar		X	X				
8-in. projectile					X		X
M55 rocket					X		X
M23 land mine							X
750-lb bomb					X		
Weteye bomb					X		
Spray tank							X
Ton container		X		X	X	X	

The features of the munitions that are significant for emergency planning are principally the quantity of agent in them and whether they include energetic material (i.e., fuze, burster and/or propellant). The former characteristic helps determine the size of a potential release, and the latter may significantly affect the mode of agent release (e.g., whether or not there is a detonation). The bombs, spray tanks, and ton containers contain the largest agent quantities; the other munitions include energetic materials. Except for M55 rockets (32,666 GB rockets and 7,791 VX rockets as of December 31, 1983), the number of other munitions and/or quantities of agents stored at TEAD are classified for national security reasons.

2.2 ACCIDENT POTENTIAL

It is impossible to know in advance all accidents that could potentially occur. It is reasonable, however, to use information developed in the CSDP risk analysis (MITRE Corporation 1987) to help bound a range of feasible accidental releases. In particular, certain characteristics of hypothesized accidents assist in emergency planning by helping define planning basis accidents. These characteristics include their lethal downwind distances under variable meteorological conditions, the duration of the release, and the mode of release (i.e., complex, fire, or spill). Appendix A provides a listing of the potential accidental releases that were identified in the CSDP risk analyses for the TEAD stockpile.

Since the number of munitions (except M55 rockets) and containers at TEAD is classified, the probabilities of these accidents, which are dependent on inventory size, cannot be divulged. What is presented below is the range of probabilities for all accidents identified in the CSDP risk analysis that could occur at TEAD.

The logic that users of the accident data base should employ is that the variation in the data base (i.e., the accidents identified in the risk analysis) should be incorporated in the planning basis accidents. Thus, one should be concerned with short- and long-distance accidental releases, short- and long-term duration events, and the different modes of release. By considering the range of values for these variables in identifying planning basis accidents, one can be more certain that affected people and emergency planning and response organizations are prepared for all plausible accidents.

2.3 RANGE OF PLANNING ACCIDENTS

As can be seen in Appendix A, the range of potential releases is extensive. Table 2.3 depicts all non-continuous values for the variables of interest (values rounded from information contained in Appendix A). The No Death (ND) downwind distance (the distance beyond which fatalities are not expected, based on application of the Army's D2PC atmospheric dispersion code [Whitacre et al. 1986]) under very stable meteorological conditions (wind speed of 1 m/s and E atmospheric stability) ranges from 1.1 to greater than 100 km.

An alternative way of portraying information about accidental releases is to identify what quantity of chemical agent would result in what lethal downwind distance under different meteorological conditions and release modes. Although this approach is unrelated to the CSDP risk analysis, it has the advantage of relating source size to downwind distance for any accidental

Table 2.3. Values for relevant accident variables

Variable	Values
Probability	10^{-4}, 10^{-5}, 10^{-6}, 10^{-7}, 10^{-8}, 10^{-9}, 10^{-10}
Duration (min.)	0, 10, 12, 15, 20, 30, 60, 61, 69, 106, 120, 240, 360
Mode of release	spill, fire, complex (combination)
ND Downwind Distance	0.6 to >100 km (1 m/s, E stability)

releases that might not have been identified in the risk analysis. Table 2.4 shows that for semi-continuous releases (e.g., as with an uncontrolled fire), VX agent results in the greatest lethal downwind distances of the three agents for all considered meteorological conditions. For evaporative releases (e.g., as from a spill), on the other hand, the downwind distance for VX agent is so low that no conceivable amount would result in an off-post release due to atmospheric dispersion; of the two realistically dangerous agents for this release mode (i.e., GB and HD), GB presents the far greater risk under all considered meteorological conditions. For instantaneous releases (e.g., as from a detonation), values are presented only for GB agent because the D2PC atmospheric dispersion code does not sufficiently incorporate the evaporation of a VX or HD explosion and provides better estimates using the semi-continuous release mode for both of these agents.

2.4 PLANNING BASIS ACCIDENT CATEGORIES

As noted in Table 2.3 and Appendix A, the range of identified potential accidental releases is large. From these releases, it is possible to identify five (5) types of releases that may usefully bound emergency planning and be considered in developing emergency planning zones (see Sect. 4). These types of releases or categories were selected principally on the basis of variance in downwind lethal distance and duration of release. The only long-distance and long-duration releases at TEAD that have been identified result from external events (e.g., earthquakes, airplane crashes, and meteorite strikes). The categories are as follows:

Category 1. A small release with no off-site fatalities.

Category 2. A moderate short-term or instantaneous release with fatalities confined within 15-20 km.

Category 3. A moderate long-term or continuous release with fatalities confined within 15-20 km.

Category 4. A large short-term or instantaneous release with fatalities possible beyond 15-20 km.

Category 5. A large long-term or continuous release with fatalities possible beyond 15-20 km.

These planning basis accident categories are used with site topography, meteorology, and population distribution (see Sect. 3) to identify emergency planning zones (Sect. 4) and appropriate protective actions for populations within those zones (Sect. 5).

Table 2.4 Approximate ND Distances (km) for Alternative Source Terms and Wind Speeds (and Stability Conditions)

kg	1 m/s (E stability) (2.2 mph)	3 m/s (D stability) (6.7 mph)	6 m/s (D stability) (13.5 mph)
Agent HD, Semi-Continuous Release			
1	0.1 km	0.1 km	<0.1 km
10	0.7 km	0.2 km	0.1 km
100	2.7 km	0.7 km	0.5 km
1000	10.4 km	2.2 km	1.6 km
Agent HD, Evaporative Release)			
1	<0.1 km	<0.1 km	<0.1 km
10	<0.1 km	<0.1 km	<0.1 km
100	0.1 km	<0.1 km	<0.1 km
1000	0.4 km	0.1 km	<0.1 km
Agent VX, Semi-Continuous Release			
1	1.0 km	0.3 km	0.2 km
10	3.9 km	1.0 km	0.7 km
100	13.9 km	3.0 km	2.3 km
1000	44.4 km	9.6 km	7.1 km
Agent GB, Semi-Continuous Release			
1	0.6 km	0.2 km	0.1 km
10	2.3 km	0.6 km	0.4 km
100	8.5 km	1.9 km	1.4 km
1000	29.0 km	6.3 km	4.6 km
Agent GB, Instantaneous Release			
1	1.3 km	0.4 km	0.3 km
10	4.1 km	1.3 km	0.9 km
100	13.3 km	3.7 km	2.8 km
1000	41.5 km	10.3 km	8.6 km
Agent GB, Evaporative Release			
1	0.3 km	0.1 km	<0.1 km
10	0.9 km	0.2 km	0.1 km
100	3.2 km	0.7 km	0.5 km
1000	10.5 km	2.2 km	1.6 km

3.0 SITE CHARACTERISTICS

The chemical storage area and proposed CSDP facility site at TEAD-S are located in a relatively isolated area in the Rush Valley portion of Tooele County, Utah. This site was originally selected in the 1940s as a storage area for chemical weapons because of its relatively dry climate and isolation. For emergency planning purposes (and specifically for determining emergency planning zones), the site is characterized in terms of natural features that may affect an accidental agent release (i.e., topographic features and meteorology). Furthermore, the location of people and resources potentially at risk (i.e., population at risk and potentially affected communities and institutions) must also be considered in determining emergency planning zones.

3.1 SITE TOPOGRAPHY

The dominant features of the Tooele area are the mountains surrounding the TEAD-S area. Table 3.1 summarizes the distance in each direction to major topographical features, with absolute and relative rise in elevation above the storage area/proposed plant site. The relative elevation between the storage area/proposed plant site and the surrounding mountains show the marked basin within which the facilities are located (see also Figure 3.1). The two lowest points in the surrounding mountains are located to the north and to the southeast at 230 feet relative rise in elevation. Except for these "passes," the surrounding mountains provide significant topographic barriers to further downwind transport of accidental releases.

Table 3.1 Topographic features in the area surrounding TEAD-S

Direction	Topographic features			
	Description	Estimated distance (km)	Estimated elevation, MSL (ft)	Elevation relative to plant (ft)
N	South Mtn	18	5,400	230
NNE	Oquirrh Mtns	18	9,000	3,830
NE	Oquirrh Mtns	18	10,300	5,130
ENE	Oquirrh Mtns	16	10,100	4,930
E	Oquirrh Mtns	14	7,500	2,330
ESE	Thorpe Hills	16	5,700	530
SE	Thorpe Hills	17	5,400	230
SSE	East Tintic Mtns	34	8,100	2,930
S	West Tintic Mtns	35	7,500	2,330
SSW	Sheeprock Mtns	37	9,000	3,830
SW	Onaqui Mtns	22	7,100	1,930
WSW	Onaqui Mtns	18	9,100	3,930
W	Onaqui Mtns	17	6,600	1,430
WNW	Stansbury Mtns	20	8,000	2,830
NW	Stansbury Mtns	32	11,000	5,830
NNW	South Mtn	20	6,100	930

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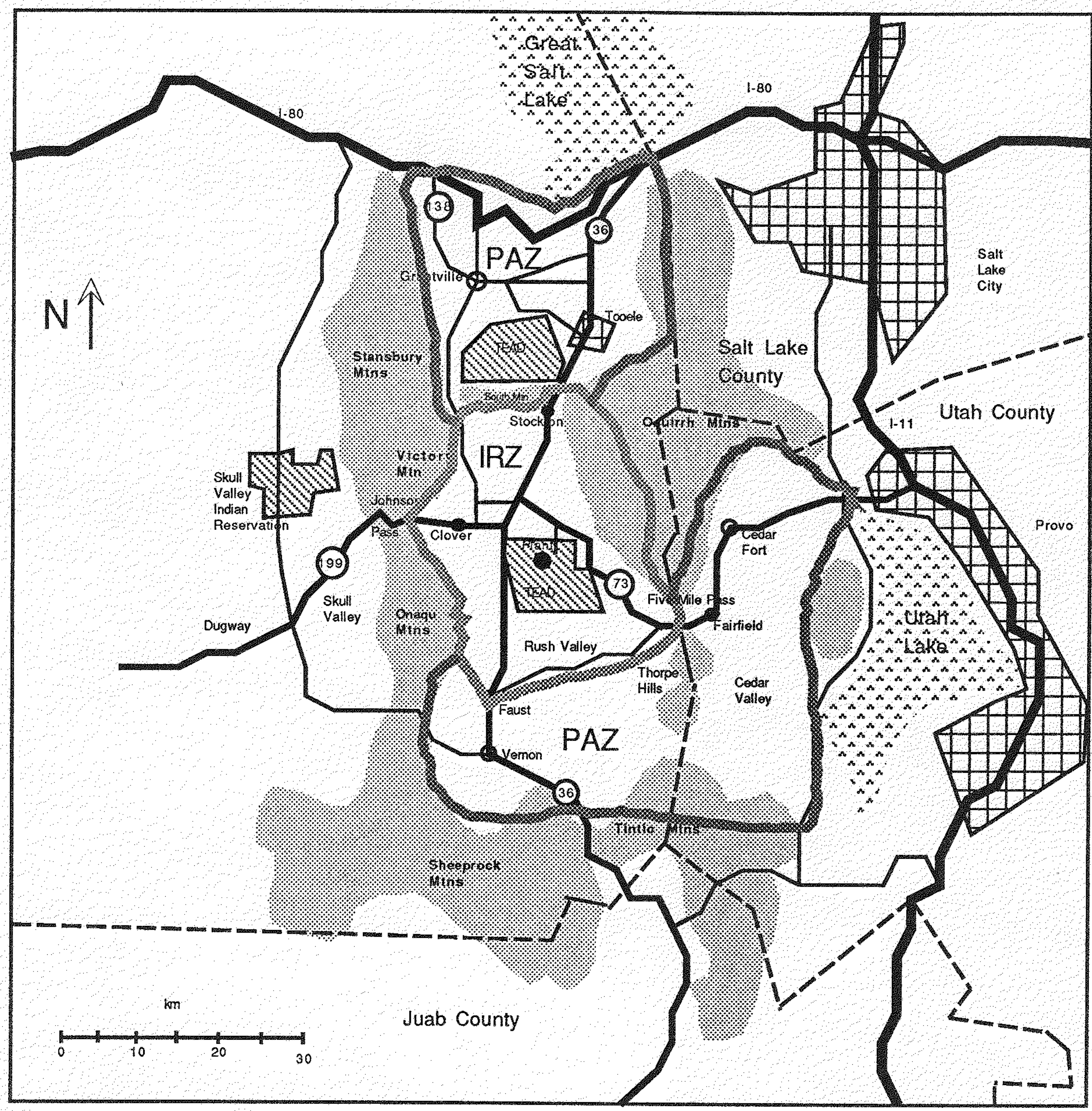

Fig. 3.1. EPZ concept for TEAD.

In the event of an accidental release, the mountains surrounding TEAD-S would function as a barrier that could contain much of the agent within Rush Valley, depending on the type and size of release and meteorological conditions. Although the degree of effectiveness is difficult to quantify, the topographic influence can be discussed qualitatively. For example, the topography would impede a ground-level release with little initial upward velocity or buoyancy more than an elevated release (e.g., from the stack) and/or a release with initial upward velocity and/or buoyancy (e.g., as caused by a fire). In the former scenario, such as an evaporative release of agent to the atmosphere following a spill, the plume would tend to "hug the ground," and would need to be lifted a greater distance to flow over the mountains, resulting in less agent crossing beyond the mountains. In the latter scenarios, such as a large explosion or fire in which the center of the plume of agent would rise by momentum and/or buoyancy to an elevated height, the flow would not be restricted as significantly by the mountains because less lift would be required for it to pass over the mountains.

In terms of emergency planning, the local topography indicates that useful planning areas are the site itself, Rush Valley (in which most moderate releases under most meteorological conditions would be contained), and the area outside the Rush Valley, especially Thorp Hills to the southeast and Tooele Valley to the north (toward which most large to very large releases would move under most meteorological conditions).

3.2 ATMOSPHERIC DISPERSION OF AGENT AND SITE METEOROLOGY

Meteorological conditions in the affected area at the time of an accidental release are especially important. They, along with the size and type of release and topographic features, help determine the extent of contamination. This section explains the role of meteorological conditions in dispersing agent and identifies the historical distribution of those meteorological conditions.

3.2.1 Atmospheric Dispersion of Agent

The most important meteorological features are wind direction, wind speed, and atmospheric stability. Wind direction determines which areas are downwind of the release and can be expected to be contaminated. Wind speed is critically important because it determines the time for a given release to reach a specified downwind distance and also affects the distances/dosages resulting from a particular release. Atmospheric stability provides an estimate of the amount of mixing that affects downwind distance and doses. In addition, air temperature is a factor in determining plume rise and, for evaporative releases, the rate of volatilization.

The D2PC computer program, developed by the U.S. Army's Chemical Research, Development, and Engineering Center (Whitacre, et al. 1986), was selected to estimate downwind doses of nerve and mustard agents resulting from accidental releases (see Sect 2). The D2PC computer program (or code) is an air dispersion model that assumes a Gaussian distribution of agent in the vertical and cross-wind directions as the agent disperses downwind. The code predicts inhaled dosage of agent expected at locations downwind of a release.

The greatest advantage of the code is that detailed information on the type of accident to be modeled is incorporated in the code. Input parameters include type of agent (GB, VX, or mustard); mode of release (explosion, fire, or spill); and duration of the release. This detailed characterization of the source term is one of the strengths of the model. A vapor depletion technique is also included in the code to estimate the removal of agent vapor from the atmosphere due to surface deposition during transit from the point of release. Although more complex dispersion codes are available, the assumption in the D2PC model of straight-line transport with non-varying meteorological conditions results in conservative estimates of the effects of releases (i.e., actual results should be less). These estimates also represent only inhaled doses and do not reflect doses resulting from skin deposition and ingestion associated with aerosol, droplet, or condensate exposure.

As is the case with all air dispersion models, the D2PC model contains inaccuracies which must be acknowledged. Specifically, the D2PC model does not account for topography, changes in wind direction over time, or any spatial changes in atmospheric conditions. The model makes a number of adjustments to compensate for these limitations, but the basic shortcomings of the model remain and have been considered in the analysis.

Use of the D2PC model, while useful as an analytical tool for estimating downwind distances for planning purposes, may be inappropriate for use in real-time conditions of an agent release. If it is used for such purposes, the available options of considering changes in wind speed, mixing height, and atmospheric stability over time should be incorporated. As noted in Sect. 1, a study is under way evaluating an assortment of dispersion models that would be useful under real-time accident conditions.

3.2.2 Site Meteorological Conditions

The climate in the TEAD-S area can be characterized as continental and heavily influenced by the surrounding mountains. Temperatures vary considerably between daytime and nighttime hours and between seasons. On calm, clear nights, colder air drains from the surrounding slopes into Rush Valley where TEAD-S is located. From November through March, minimum temperatures can drop below -17 degrees C (0 degrees F), and temperatures below -23 degrees C (-10 degrees F) are possible from December through February. Temperatures usually moderate appreciably during the daytime. Maximum temperatures are frequently above 32 degrees C (90 degrees F) during July and August, but temperatures greater than 37 degrees C (100 degrees F) are extremely rare.

The area is noted for plentiful sunshine, low relative humidity, and light precipitation. This is due to the great distance from major sources of moisture (the Pacific Ocean and the Gulf of Mexico) and the influence of the mountains between the moisture sources and TEAD-S that "squeeze" much of the moisture out of the air into precipitation while it is lifted over the mountains. Normal annual precipitation at TEAD-S is only about 28 cm (11 in) and is distributed fairly evenly throughout the year. Almost all of the winter precipitation is in the form of snow, and spring and fall snowstorms are fairly common. Annual snowfall at TEAD-S averages about 100 cm (40 in). The probability of a tornado striking TEAD-S is very remote (Thom 1963).

The prevailing winds are from the southeast in the TEAD-S area, with large frequencies also from the adjoining SSE and ESE directions. A secondary peak occurs from the NNW direction. These directions are aligned with the orientation of the mountain ranges on either side of TEAD-S; the mountains channel the flow along the axis of Rush Valley (see Fig. 3.1). The average wind speed is about 3.6 m/s (8 mph) near the surface. The wind rose in Fig. 3.2 depicts the annual joint frequency distribution of wind speed and wind direction at TEAD-S. In this graph, winds blowing from each direction are plotted as individual bars that extend from the center of the circular diagram. Wind speeds are denoted by bar widths; the frequency of wind speed within each wind direction is depicted according to the length of the bar. Note that the points on the wind rose represent the directions from which the winds come; normal emissions from the disposal facility or accidental releases from the disposal facility or storage area would travel downwind in the opposite direction. The frequency is given as the percentage of the total number of measurements. Figure 3.3 provides an alternative means of portraying similar information, for all atmospheric stability conditions. Appendix B provides graphs with information similar to that provided in Fig. 3.3, for separate wind speed classes; each graph in the appendix stratifies wind direction by stability condition.

Meteorological conditions would play a vital role in determining the degree of impediment or containment surrounding topography would cause in the event of an accidental agent release.

- During stable atmospheric conditions (e.g., a temperature inversion) with light winds, the mountains would cause a "damming" effect in which most of the agent would be diverted at the mountains' base to flow parallel to the base of the mountains rather than being lifted.

- During unstable conditions, however, the agent would mix more easily in the atmosphere and cross the mountains with less difficulty. Also, during high-wind conditions, the wind could lift the plume over the mountains more readily. It should be noted that during unstable or high-wind conditions, the atmosphere would also dilute the agent much more readily, resulting in lower concentrations of agent reaching the same downwind distance.

Wind direction is an important factor in examining the effectiveness of the mountains as barriers because of the variation in height of the mountains surrounding TEAD-S in different directions. Obviously, the higher mountains would be more effective in containing an accidental release of agent within Rush Valley. For most wind directions, the elevation differential between TEAD-S and the surrounding mountains is so substantial that very little agent would be expected to pass beyond them, regardless of the type of release or meteorological conditions. Two breaks in the surrounding mountains, however, are oriented to the north and southeast of TEAD-S (see Table 3.1 and Fig. 3.1). In the event of an accidental release in one of these downwind directions, the topography would only partially impede the agent plume for most types of releases and meteorological conditions.

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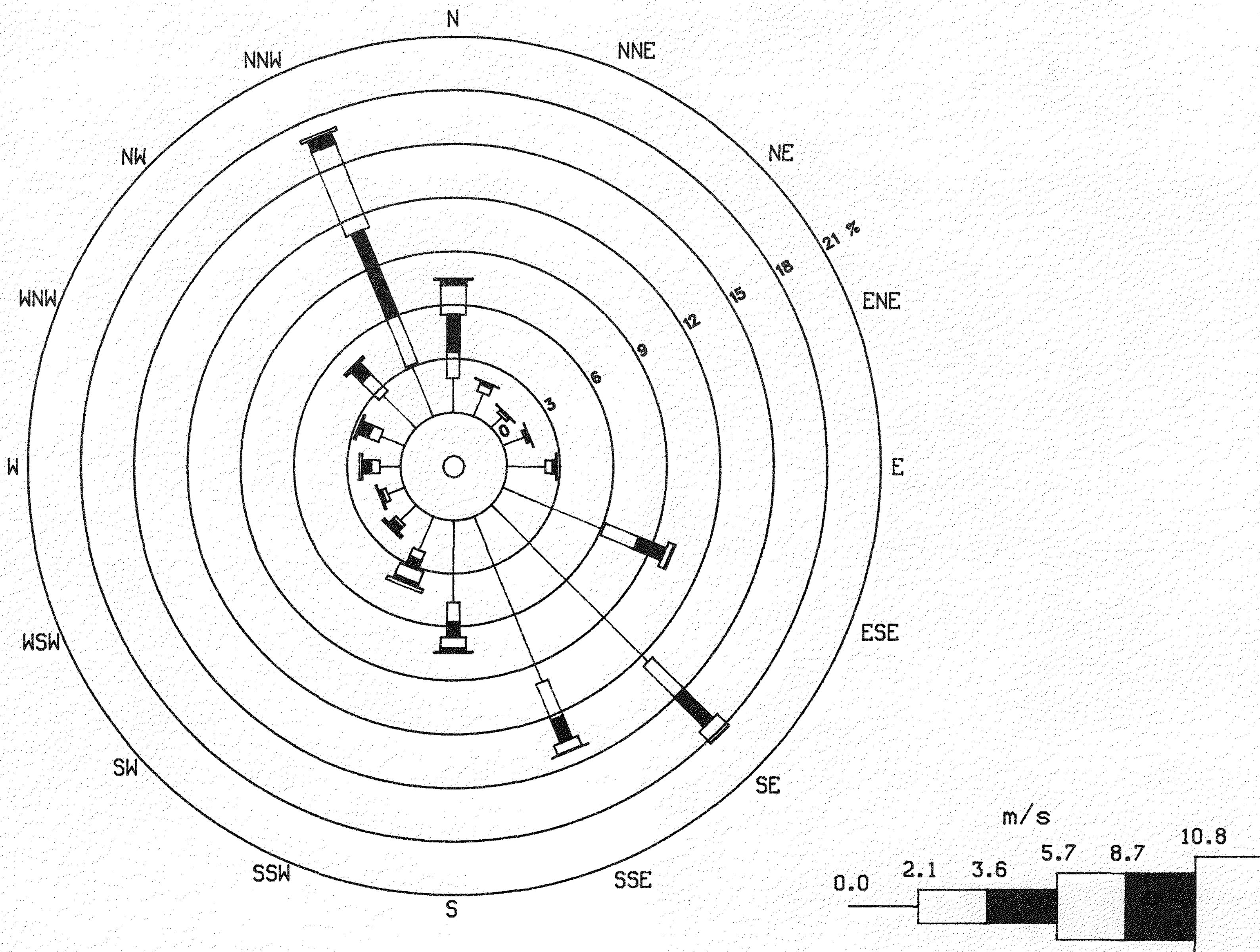

Fig. 3.2. Wind rose for TEAD for the period 11/1/86–10/31/87.

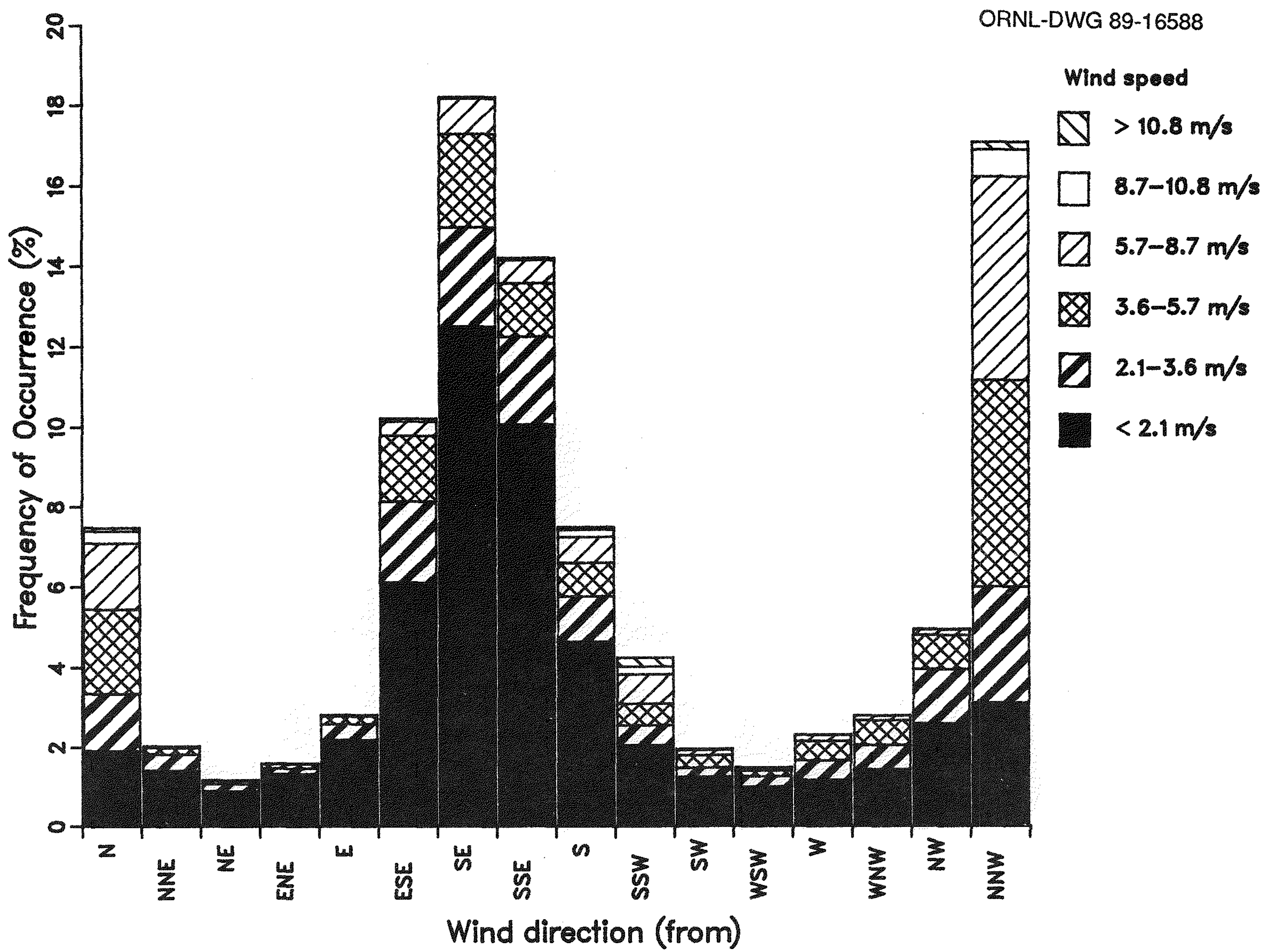

Fig. 3.3. Distribution of wind speeds and directions (TEAD Tower #9 data, November 1986–October 1987).

3.3 POPULATION AT RISK

The ultimate objective of emergency planning and preparedness is to protect the public and reduce the number of casualties and fatalities in the event of an accidental release of agent. Although there are likely many ways to consider population at risk for emergency planning purposes, it is important is to ensure that all potentially affected persons, during the day or night, are considered in planning. Thus, it is important to know where people are, whether they require different protective actions because of where they are (e.g., children at school during the day and at home at night), and whether any transient populations might be present at the time of a release.

The distribution of the population in the vicinity of TEAD-S can be described in terms of four fundamental categories: (1) nighttime population which is characterized in terms of residential population; (2) daytime population which is distributed differently than nighttime population may be characterized in terms of place of employment (for working adults) and schools (for children); (3) institutional populations, characterized in terms of schools, hospitals, nursing homes, and day-care centers; and (4) other special populations including transient populations and people located in the vicinity for recreational purposes.

The chemical agents/munitions storage area is located approximately 1.5 km from the nearest installation boundary, and the proposed CSDP plant site is located approximately 3 km from the nearest installation boundary. Daytime and nighttime personnel in restricted access areas [i.e., storage and operations, and the Chemical Agent Munition Destruction System or (CAMDS)] are specially equipped and trained for operations in toxic environments. In non-restricted areas (e.g., the laundry area and the administrative area), on-site training and equipment are not routinely required, and personnel in these areas may require additional time for implementing appropriate protective actions. Finally, the extent to which people living in installation housing (approximately 90 people), located approximately 4 km east of the chemical agent storage area, are trained and equipped for potential emergencies is uncertain (this housing is expected to be vacated by the time disposal operations begin). These on-site people would be the nearest human receptors for an accidental release.

The nighttime population within 2 km of either the storage area or the proposed plant site is limited to on-site population; however it is estimated that 2 people live within 5 km. Another 99 people live between 5 km and 10 km of the proposed plant location, and 967 people between 10 and 20 km from the site, for a total of 1,068 within 20 km of the proposed location. About 22,900 additional people lived between 20 and 35 km of the plant. In the immediate area, about 400 persons live in the Rush Valley Township, and approximately 1,100 in the entire Rush Valley (see Table 3.2).

Data concerning daytime population in these areas have not been systematically collected but can be by local agencies. Perhaps the most practical approach to estimating such numbers is by identifying and characterizing places of employment, institutional populations such as schools and day-care centers, and other institutional populations in the potentially affected area. What is currently known is that the dominant employer in the area is TEAD, with approximately 3,800 people working at TEAD-N and TEAD-S combined. Because the TEAD-S population is known (about 450), it is estimated that approximately 3,350 people are concentrated in and around the TEAD-N area. In addition, there are a few establishments in Stockton and Vernon, and perhaps a few more in the Clover, St. John, and Rush Valley Township areas.

The school populations in the area are summarized in Table 3.3. The only institution in the Rush Valley is an elementary school in Vernon with 34 students as of May, 1988. Schools in the Tooele Valley are located in Tooele and Grantsville. Tooele has five elementary schools with a total enrollment of approximately 2,700 students and a special education school of 28 disabled youths. Tooele also has four middle and junior/senior high schools with approximately 2,100 students. The only health care facilities are Tooele Valley Hospital (33 beds) and Tooele Valley Nursing Home (78 beds), both located on the same site in the city of Tooele. Additional hospitals further away that might be used as reception centers in the event of an accidental release are identified in Appendix C. Grantsville has an elementary school with an enrollment of 639 and middle school, and high school with an enrollment of 872.

Perhaps the most problematic populations to consider in emergency planning are the special populations associated with recreational activities in the public, private, and national forest lands surrounding the area. While comprised of relatively few people at any given time, these people are widely distributed yielding a sparse concentration in any one place. However, during some special events, like National Guard exercises (e.g., FIREX 88), these populations can be as large as 20,000 people, with concentrations of as many as 3,000 support personnel within the boundary at TEAD-S. While these special events and even recreational users are of relatively short duration, they represent a significant emergency planning challenge.

Table 3.2 **Estimated 1986 population distribution around the TEAD-S proposed plant site***

Direction	Incremental population data at specified distances (km)							
	0-1	1-2	2-5	5-10	10-20	20-35	35-50	50-100
N	0	0	1	1	402	10,550	431	1,103
NNE	0	0	1	1	0	6,162	16,117	227,163
NE	0	0	0	3	49	652	94,624	529,798
ENE	0	0	0	3	3	252	28,715	31,275
E	0	0	0	8	60	675	9,192	155,090
ESE	0	0	0	5	53	316	184	43,799
SE	0	0	0	2	31	104	180	7,848
SSE	0	0	0	2	13	34	696	1,806
S	0	0	0	2	7	22	18	1,946
SSW	0	0	0	2	7	211	0	73
SW	0	0	0	2	4	6	3	0
WSW	0	0	0	2	1	902	357	493
W	0	0	0	2	1	0	0	0
WNW	0	0	0	57	251	0	1	1
NW	0	0	0	5	85	0	104	539
NNW	0	0	0	2	0	3,024	2,115	718
TOTAL	0	0	2	99	967	22,910	152,737	1,001,652

* The 1986 population of counties and incorporated places, as estimated by the U. S. Bureau of the Census, was provided by the Data Resource Section of the Utah Office of Planning and Budgeting. ORNL staff used these data to estimate the 1986 population of each census enumeration district within 100 km of the proposed site based on the following assumptions: (1) the percentage change in the population of an incorporated place between 1980 and 1986 was shared by each enumeration district within that place, and (2) the percentage change in the population of the unincorporated portion of a county was shared by each enumeration district in the unincorporated portion of the county.

Table 3.3 Educational institutions within 35 km of the proposed CSDP plant site

City	Schools			
	Elementary	Number of students	Middle and jr/sr high	Number of students
Vernon	1	34	0	0
Tooele	5	2,652	4	2,117
Grantsville	1	639	2	872
Dugway	1	253	1	190

Source: L. LaFever, Pupil Account Specialist, Tooele County School District, Tooele County, Utah, personal communication with G.O. Rogers, Oak Ridge National Laboratory, Tennessee, September 1, 1988.

3.4 COMMUNITIES AFFECTED

In the event of an accidental release, emergency response will likely be coordinated by the installation through local governmental jurisdictions, including cities, towns, and counties. Table 3.4 provides a listing of potentially affected communities within 35 km of the proposed plant site in the Rush Valley, Tooele Valley, and other locations. This table also identifies the distance and direction from the proposed plant site.

Table 3.4 Communities within 35 km of proposed CSDP plant site by distance and direction

Community[1]	1986 population	Direction	Distance (km)
	Rush Valley		
Ophir	50	NE	12
Mercur	NA[2]	ENE	12
Rush Valley Township	400	Not applicable	Not applicable
Faust	NA	SSW	12
Clover	NA	WNW	10
St. John	NA	NW	11
St. John Station	NA	NNW	9
Stockton	410	N	17
Vernon	200	SSW	23
Lofgren	NA	S	31
	Tooele Valley		
Bauer[3]	25	N	19
Tod Park	NA	N	22
Tooele	15,760	N	27
Erda	NA	N	35
International	NA	NNE	30
Grantsville	5,130	NNW	35
Marshall	NA	N	34
	Other communities <35 km		
Lark	500	NE	33
Cedar Fort[3]	269	N	21
Fairfield[3]	90	E	22
Dugway[3]	1,646	WSW	34
Willow Springs	NA	WNW	22

[1] Unless otherwise noted, source is U. S. Department of Commerce, Bureau of the Census 1988.

[2] NA = not applicable

[3] Source: Rand McNally & Co. 1986.

4.0 EMERGENCY PLANNING ZONE (EPZ) DEFINITION

The EPZ definition is a crucial part of the planning basis. It should be determined by a series of factors including the distribution of potential accidents, population, and terrain. The EPZ boundaries should be flexible and changes should be made in response to other program decisions. The selection of EPZ boundaries is based on a conceptually simple methodology, as outlined below. Following a discussion of this methodology (Sect. 4.1), it is applied to the TEAD stockpile (Sect. 4.2) and a recommended EPZ and set of boundaries are identified (Sect. 4.3). The final determination of emergency planning zone boundaries will be made collectively by affected local governments, state government, the Department of the Army, and the Federal Emergency Management Agency.

4.1 METHODOLOGY FOR SELECTING EPZ BOUNDARIES

This section presents a systematic methodology that can be applied to identify emergency planning zones at sites storing unitary chemical weapons and agent in the continental United States. This methodology focuses planning on site-specific stockpile storage and disposal risks and other site-specific concerns such as population distribution, meteorology, and topography.

The next section presents a theory of emergency planning zones. That is followed by a discussion of the spatial distribution of risk and hazard. The fourth section outlines how geographical boundaries can be established. Finally, application criteria are specified to operationalize the procedure.

4.1.1 Emergency Planning Zone Concepts

4.1.1.1 A zone-based theory of emergency planning

The use of zones is not a novel approach in emergency planning. Floodplains and Floodways are defined in the national flood insurance program. California has special planning zones in areas of high earthquake risk. For hurricanes Maximum Envelopes of Water (MEOWS) drive evacuation planning. Zones have also been established for nuclear power plant emergency planning. In this section we present a theory of how to structure planing zone concepts.

4.1.1.2 Hazard distribution

A variety of accidents associated with on-site stockpile disposal can occur. Logically, they can occur at a chemical weapons storage building/igloo, at the incinerator plant site, or in transit. The distribution of hazard from these accidents is based on a number of factors including how much agent is released, how it is released, the duration of the release, the meteorological conditions during the release, and the effects of topography on agent dispersion. Source terms (or the amount of agent released) can range from small amounts with little potential for health risks to very large amounts. The hazard from any single accident scenario (i.e., eliminating the source term variability) cannot be easily predicted because of the remaining variables that affect distribution. On average, the risks from any single accident decrease as the distance away from the point of release increases. Thus, the potential for being exposed from agent in any given accident are greater as one gets closer to the accident site. The potential consequences of exposure also decrease with distance. The risk that an exposure would cause fatalities are greater as one gets closer to the accident site.

4.1.1.3 Level of effort

As the risk and hazard from an accident decrease and distance from the source term increases, the level and type of planning required also change. Lower risk means that response is less likely to be needed. Lower hazard means that exposure is less likely to occur. Greater distance means that more time is available for response. The major planning and response elements that are affected include mobilization of emergency personnel, communication systems, alert and notification systems, protective action options, decontamination and medical resources, public education and information, training needs, exercises, and mass care/relocation facilities. For example, for resources near an accident site a very rapid warning is needed; as distance increases the amount of available response time increases, relaxing the need for rapid warning.

4.1.1.4 Number of zones

Since it is perhaps impossible and at least unrealistic to implement emergency response plans that vary continuously with distance, it is necessary to establish zones to differentiate activities. This may be characterized as a class interval problem. This problem raises a number of thorny issues. How many zones are appropriate? How should the boundaries of the zones be established? At what distances should zones change? How can zones be differentiated so that people living near boundaries understand the inherent differences in planning required?

The Radiological Emergency Planning (REP) Program for fixed site nuclear power facilities uses a 2 zone concept (ref). The Plume Exposure Pathway Zone has a radius of about 10 miles while the Plume Ingestion Pathway Zone has a 50 mile radius. The 10 mile criterion was established based on probabilistic risk assessment of reactor accidents. Critics have suggested that such a zone should be changed to anywhere from a 1 to a 25 mile radius.

The *ERCP* for the Chemical Stockpile Disposal Program described an alternative set of 3 planning zones based on a concept developed at ORNL. Emergency planning zones (EPZ) concepts were developed in that document to support the development of fixed-site and transportation alternative emergency response concepts for the Final Programmatic Environmental Impact Statement (FPEIS) and the Army's deliberation concerning a programmatic decision. EPZs, developed in consideration of the risk analysis, available response time, distance, and protective action options, establish the areas where the emergency response concepts were applied. The EPZ concept and its three zones reflect the differing emergency response requirements associated with the potential rapid onset of an accidental release of agent and the amount of time that may be available for warning and response. They were developed in recognition of the importance of comprehensive emergency response planning and support systems for rapidly occurring events and the critical nature of such programs in areas nearest the release point.

The EPZs were intended to guide the development of emergency response concepts, and were not intended to be applied mechanistically or inflexibly to specific sites or alternatives or to a specific accident scenario. The development of actual EPZs takes into account unique political, social, geographical, and stockpile characteristics of each site. Conceptually, the criteria for establishing the EPZs are applied consistently across the program; however, specific configurations and associated distances may vary from site to site.

The EPZs were partitioned into three specific subzones (see Fig. 4.1): the innermost zone is an immediate response zone (IRZ), the middle zone is a protective action zone (PAZ), and the outermost zone is the precautionary zone (PZ). The subzones discussed in the FPEIS were based on the types of accidents identified for all of the sites and the amount of time available to pursue appropriate protection actions. The EPZs for site-specific emergency response concept plans, in contrast, are based on the hazards posed by site-specific stockpiles and meteorological, topographical and demographic conditions.

Immediate response zone. Those areas nearest to the stockpile locations should be given special consideration, because of the potentially very limited warning and response times available within those areas. An IRZ is defined for the development of emergency response concepts that are appropriate for immediate response in areas nearest to the site.

The IRZ is defined as an area inside the PAZ where prompt and effective response is most critical. Because of the potentially limited warning and response time available in the event of an accidental release of chemical agent, the IRZ extends to a distance having less than 1 hour response time under 3 meters/second (about 6.8 miles per hour) wind speeds. This area is the one most likely to be impacted by an accidental release of chemical agent and would be affected by any release that escaped installation boundaries. These impacts are within the shortest period of time and are characterized by the heaviest concentrations. Emergency response concepts in the IRZ should be developed to provide the most appropriate and effective response possible given the constraints of time.

The full range of available protective action options and response mechanisms should be considered for the IRZ (see Sect. 5). The principal protective actions (sheltering and evacuation) need to be considered carefully, along with supplemental protective action options that can significantly enhance the protection of public health and safety. Sheltering may be the most effective principal protective action for the IRZ, because of the potentially short period of time before impacts may be expected by a released agent. In-place protection is particularly important in areas within the IRZ nearest to the release point, since the time may not be available for people within downwind areas of the IRZ to complete an evacuation. The suitability of sheltering depends upon a number of other factors, including the type(s) and concentration(s) of agent(s), expedient or pre-emergency measures taken to enhance the various capacities of buildings to inhibit agent infiltration, the availability of individual protective devices for the general public, the accuracy with which the particular area, time, and duration of impact can be

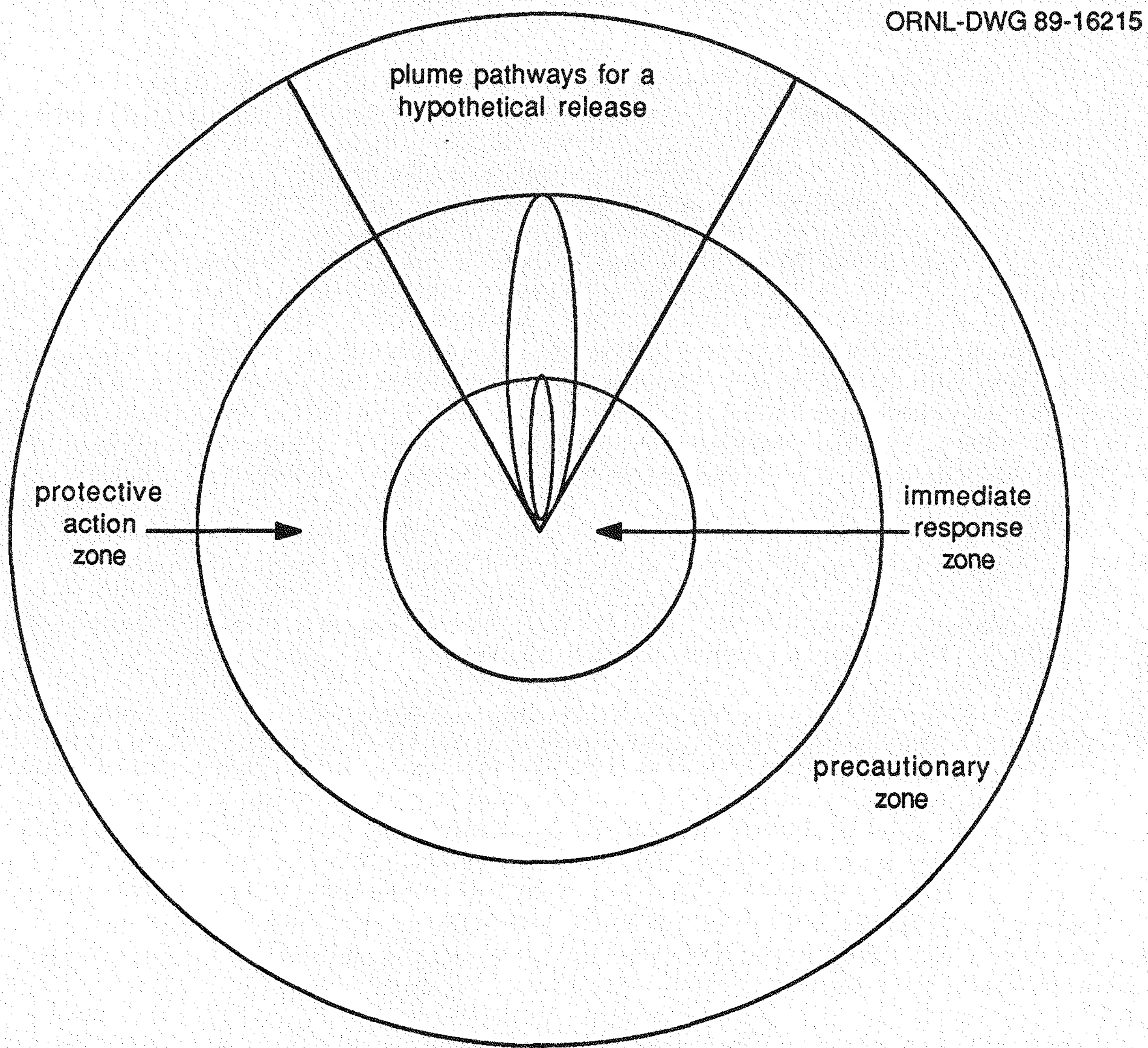

Fig. 4.1. Three-zone concept for the emergency planning zone.

projected, and the ability to alert and communicate instructions to the public in a timely and effective fashion.

The capability to implement the most appropriate protective action(s) very rapidly is critical within the IRZ. A thorough analysis of the IRZ at each storage/stockpile location should be conducted, and a methodology for determining the appropriate protective action(s) under various accident scenarios should be established to reduce decision-making at the time of an actual chemical agent release to a minimum. This analysis would likely identify certain areas within the IRZ which would implement sheltering under most accident scenarios, with evacuation only available as a precautionary measure prior to a release. Subzone areas may be defined to accommodate the selective implementation of different protective actions within portions of the IRZ. Given a reasonably effective capability to project the area of impact and predict levels of impact at the time of a release, it may be appropriate to implement sheltering in areas close to the release point within the expected plume and evacuation in areas not immediately impacted.

Protective action zone. The PAZ defines an area where the available emergency response times and the hazard distances associated with them are sufficiently large to allow most people to respond to an emergency effectively through evacuation. Although the primary emergency response may be evacuation, other options should be considered.

The principal emergency response, evacuation, should be considered carefully to ensure effective implementation. It is likely to be the most effective emergency response in the PAZ if time is sufficient to permit orderly egress. However, evacuation, like other protective actions, requires warning. Because time remains limited in the PAZ, effective warning systems are needed to both alert people to the potential for harm and inform them of the most appropriate actions required. Available time for protective action varies with agent type, accident, and meteorological conditions at the time. These conditions will require careful consideration during site-specific emergency planning.

Precautionary zone. The PZ is the outermost EPZ and extends conceptually to a distance where no adverse impacts to humans would be experienced in the case of a maximum potential release under virtually any conditions. The actual distance may vary substantially, based upon the circumstances of an accident occurrence, and would be determined on an accident-specific basis. In this EPZ, the protective action considerations are limited to precautionary protective actions and actions to mitigate the potential for food-chain contamination as a result of an agent release.

The time frame for the PZ is likely to be sufficient to implement protective actions without prior comprehensive and detailed local planning efforts. Given the likelihood of substantial warning and response times for areas within the PZ, precautionary measures can be planned and implemented at a state or regional level. The development of specific protective actions for the PZ should be based on site-specific needs and analyses. Sheltering in the PZ would largely be a precautionary protective action to reduce the potential for exposure to nonlethal concentrations of chemical agent. Evacuation could also be implemented as a precautionary protective action in this zone. The means for implementing the agricultural protection and other precautionary activities could be based principally on broad-area dissemination of emergency public information at the time of an accidental release of agent. Because of the substantial warning and response time available for implementation of response actions in the PZ, detailed local emergency response planning is not required, but coordination of local emergency managers may prove useful.

4.1.2 Determining Factors for the Spatial Distribution of Risks

4.1.2.1 Hazard

The probabilistic risk analysis (PRA) for the stockpile disposal program (GA Technologies 1987a, b, c, and MITRE 1987) identifies a range of accidents with potential off-site consequences (see Sect. 2 for a discussion of the distribution of accidents identified for TEAD). It does not identify accidents with small consequences (less than 0.5 km lethal downwind distance under 1 m/s winds and very stable atmospheric conditions), extremely low probabilities (less than 10^{-8}), or accidents resulting from deliberate acts of sabotage or terrorism. Given the caveats that risk analyses do not identify all possible accidents, and that historic accidents of significant size (TMI, Chernobyl, Bhopal) have not been predicted by risk analyses, the PRA does a credible job in identifying a range of events that can serve to formulate planning basis accidents.

The events include storage accidents, transportation accidents, handling accidents, and plant operations accidents. These are caused by external events such as earthquakes or plane crashes, human errors such as feeding munitions into the wrong incinerator or puncturing a munition with a fork lift, and mechanical failures such as a fire or a truck crash.

Chemical agent is released from accidents in several different ways. The type of release determines how much agent is available in forms that can be transported downwind. Modes of release include explosions or detonations which cause agent to aerosolize virtually instantaneously into small particles, fires which vaporize agent on a semi-continuous basis, spills which cause agents to evaporate, or some combination resulting in a complex release. Furthermore, releases can be of short duration, which results in a discrete puff or cloud which moves downwind, or of long duration, which results in a plume extending downwind over a longer time frame.

The height of a release and whether or not fire is present is also important. The height may be influenced by agent coming out of a stack versus a ground-level release, or a release may be elevated due to an explosion which propels it into the atmosphere. Fires cause thermal buoyancy which lifts the agent to greater heights. At greater heights the agent is likely to travel downwind more quickly but lower ground-level concentrations of agent would occur due to increased mixing.

4.1.2.2 Meteorology

Meteorological conditions, along with topography and the nature of the release, determine in what direction and how a release of agent disperses in the environment. Wind direction does not determine dispersion but does establish upwind and downwind directions. The primary factors which determine dispersion are wind speed and atmospheric stability. Secondary meteorological consideration which influence and are incorporated in atmospheric stability include heating/cooling and mechanical stirring. Under certain conditions, low-level inversions could trap releases close to the ground.

When a release occurs the wind direction obviously determines the general direction the plume will move. Shifts in wind direction will cause the plume to meander or, if viewed from above, to snake back and forth. Plumes are more likely to meander under low wind speeds than at high wind speeds.

Mechanical mixing and heating and cooling are the main determinants of stability or the amount of mixing that occurs as a cloud or plume move downwind. When a high level of mixing occurs the plume travels less distance downwind but cover a wider area. When conditions are more stable, little mixing occurs and longer and narrower plumes result.

4.1.2.3 Topography

Topography affects the dispersion of agent in two significant ways. First, the roughness of the terrain helps determine the amount of turbulence. The larger the obstacles that wind flows over the more turbulent the atmosphere. Thus, plumes travel further over smooth terrain than rough terrain. Second, landscape features such as mountains and valleys block the flow or channel the flow of a plume. As a plume collides with a mountain or a dike, the concentration increases on the windward side of the obstacle as the agent pools and the plume bulges out against the obstacle. Conversely, the concentration on the lee side of the obstacle is reduced. If the feature is high enough, particularly under stable conditions, the plume will be trapped. If it is a minor feature, pooling will still occur but the plume will spill over the topographic barrier at a reduced concentration.

4.1.2.4 Population

An agent is of little immediate human health concern unless people are exposed to agent in the atmosphere. Exposure can be through contact with skin or through inhalation. Since response is dose-driven, the critical parameter is the concentration integrated over time or the cumulative amount of agent to which one is exposed.

4.1.3 Boundary Determining Factors

Planning zones can be established as concentric circles with fixed radii. Alternatively, a fixed radii can provide guidance with the boundaries being determined by political, human, and topographical features of the environment. The latter approach is strongly preferred because people can more easily identify features of the local environment than they can a line on a map.

Emergency planning and response capacities are usually organized by political units—counties, parishes, cities, townships, and so forth. Thus it is desirable to have planning zones coincide with political boundaries, particularly when a boundary differentiates responsibilities for emergency planning.

The process of human development of an area produces artifacts of a built environment. Some, such as streets, highways, rail lines, canals, and electric transmission lines, provide useful boundaries for planning zones.

Natural features provide useful boundaries, particularly when they serve as barriers to agent dispersion. This would include mountains, bluffs, canyons, and dikes. Other natural features such as rivers that may not impede dispersion can also be useful boundaries as long as they are not mistakenly identified as barriers to dispersion.

4.1.4 A Methodology for Delineating Zones

Based on the previous discussions, this section specifies a systematic methodology for establishing emergency planning zones. The method follows a sequence for establishing concentric radii for the generic zones, and then drawing boundaries based on environmental factors.

4.1.4.1 Hazard-generated concentric boundaries

Two factors concerning hazard are considered in the criteria. The first is the time dimension—how much time is available before a threat exists. The second concerns the threat per se—what is (are) the geographical area(s) at greatest risk. These are used to determine the recommended distances for generic IRZ and PAZ planning zones at a site. The boundaries of the PZ (precautionary zone) are not specified although local governments may wish to set them based on catastrophic accident potential at a site (see below).

Time. Time-distance relationships are shown in Figure 4.2 for 3 different assumed wind speeds. These are used to help estimate the boundaries of the IRZ and PAZ. For the IRZ, assuming a release of agent with little or no lead time, the leading edge of the agent plume roughly corresponds to wind speed. With winds at 1 m/s, it will take about 17 minutes to reach 1 km and 167 minutes to travel 10 km. At 3 m/s it will take almost an hour to reach 10 km. Unless a catastrophic accident occurred, it is unlikely that source terms would be large enough, except under stable meteorological conditions, for the plume to travel a distance of 10 km. If one assumes that preplanned emergency response in the PAZ requires at least 1 hour to mobilize, then at least a 10 km immediate response zone is needed.

Under this concept a PAZ would begin at about 10 km. The outer edge of the PAZ is more flexible. Assuming that 5 hours are needed to mobilize response with little or no advance preparation, and that agent traveled at 1 m/s, then about 18 km would be needed for a PAZ. More conservatively, assuming a 2 m/s wind speed, the PAZ extends to approximately 35 km. With advanced preparation, less time may be required to mobilize a response within a PAZ, but, alternatively, winds may travel faster (e.g., at 3 m/s), thus still requiring a relatively extended PAZ.

Threat distribution. Using the D2PC atmospheric dispersion code developed by the Army (Whitacre, et al. 1986), threat is represented by the distance agent

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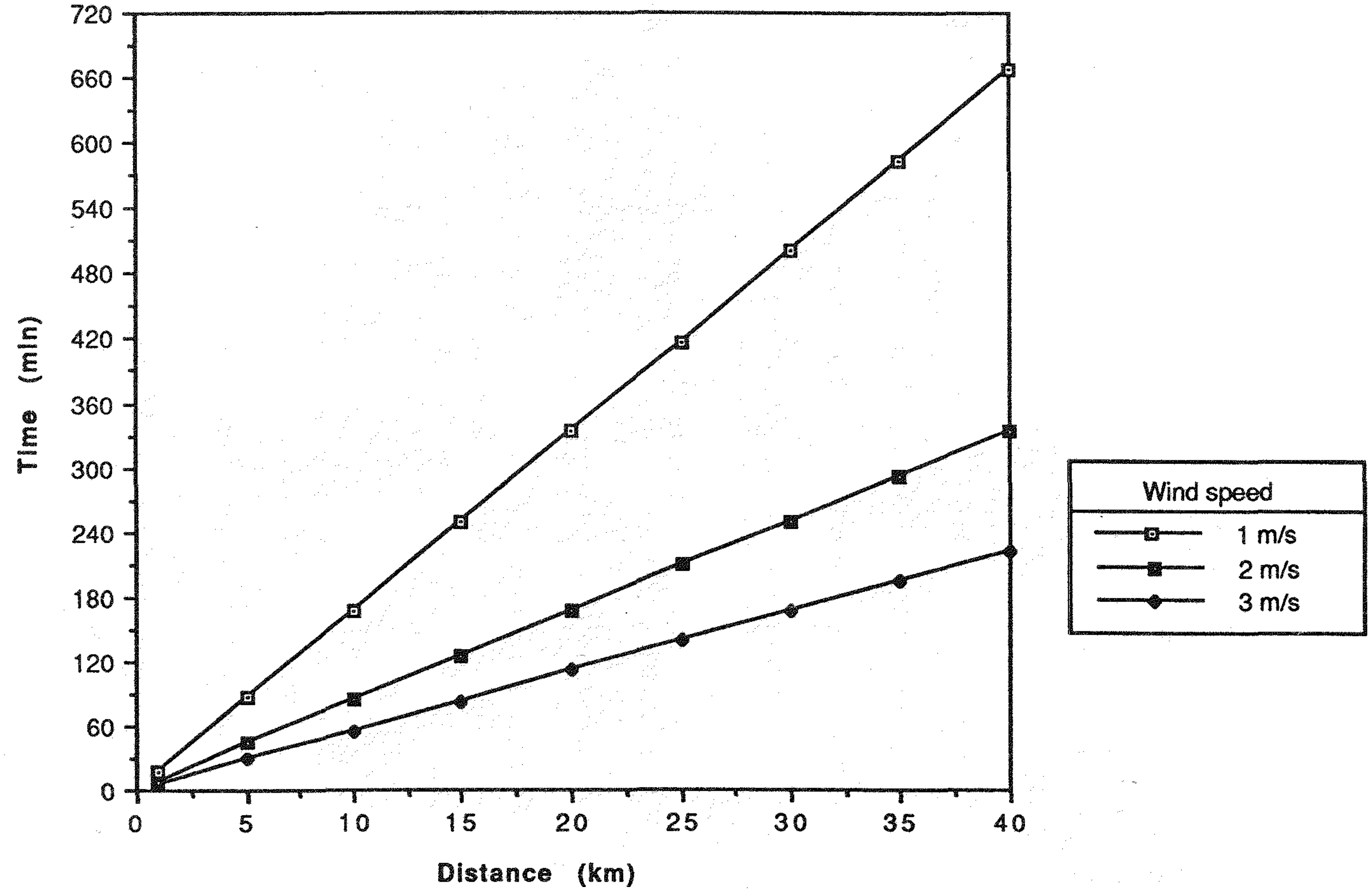

Fig. 4.2. Relationship between distance traveled and time of plume travel.

can travel and potentially cause fatalities to healthy adult males. Downwind no death dose distances were calculated for each accident scenario using the D2PC code. We have explicitly excluded releases resulting from external events (e.g., earthquakes, meteorite strikes, plane crashes) for the rationale described in Sect. 4.1.5.3.

The IRZ should contain lethal plumes from credible accident scenarios under all except stable meteorological conditions (when sufficient time exists to respond because of the associated low wind speeds). Thus, the IRZ distance should be expanded from 10 km as represented in the *ERCP* to contain the downwind no deaths distances of credible non-external event accidents under 3 m/s and D stability meteorological conditions (plus an uncertainty band of approximately 50 percent).

The PAZ should contain plumes from credible accident scenarios under more stable weather conditions. Thus, the PAZ distance be adjusted from 35 km as identified in the *ERCP* to contain the downwind no deaths distances of credible non-external event accidents under 1 m/s and E stability conditions (plus an uncertainty band of approximately 50 percent).

4.1.4.2 Setting the actual boundaries

The generic concentric-radii boundaries based on the above criteria should be adjusted based on a number of criteria:

- The boundaries of the generic IRZ and PAZ should be adjusted to account for local topographical features which may interact with meteorology to affect dispersion.
- The boundaries of the IRZ and PAZ should not bisect a populated urban area but should be adjusted to include those areas.
- Where boundaries of the generic zones coincide approximately with political boundaries, the political boundary should be used as the boundary of the zone.
- Where no political boundaries coincide, it is desirable to use a feature of the human landscape such as a road, highway, or rail line or a natural feature such as a river or creek as the boundary of an IRZ or PAZ.
- When no natural, political, or human boundary exists, a concentric circle with the appropriate radius may be used as a boundary.

4.1.4.3 Dealing with catastrophic events

In recommending generic distances based on hazard and accident distributions, we excluded external event accidents. This was done for three reasons. First, such events are often low probability events that contradict a common sense approach to planning. Thus, one does not plan for meteorite strikes or planes falling out of the air as initiating events. Second, the event that causes the accident may also reduce or eliminate response capabilities as in the case of the earthquake. Third, such events include large consequence events that stretch atmospheric dispersion modeling capacities beyond its limits, resulting in downwind hazard estimates that are fairly unreliable. In any case, we believe that detailed planning is not needed when time allows a response to be implemented as an expansion of activities beyond the PAZ.

If emergency planners are concerned with large catastrophic events, a formal designation of the precautionary zone can be made. In no cases can we envision it extending more than 100 km. It is almost impossible to develop an accident scenario and transport conditions that would lead to a lethal dose of agent to exceed that distance. It is also possible to increase preparedness in this zone beyond what is suggested by the *ERCP*.

4.1.5 Conclusions regarding the EPZ boundary determination methodology

In this section we have attempted to lay out a rationale and a systematic methodology for establishing emergency planning zones around the facilities that will dispose of chemical weapons. The approach combines procedures that are the result of scientific calculations (but still subject to large uncertainties) along with ones that hold practical appeal in an attempt to develop zones which have both scientific and political reality. In addition, it is hoped that the approach makes common sense; if it belabors the obvious, then we have succeeded more than we had expected.

The approach is not flawless. We cannot be certain that the risk analysis covers all events. Atmospheric dispersion models can only roughly predict downwind dispersion. Information about the distribution of people, resources, and topographic features, and knowledge of relevant meteorology at the time of a release are all limited and, in some cases, changing. Lines on a map do not adequately differentiate levels of risk.

Despite such caveats the purpose of establishing zones is not one of predicting an accident, but rather to allocate resources and to plan the proper responses to a large range of accidents. It attempts to take a complex problem with many relevant variables and reduce the problem to one that can be more effectively managed than an unknown or poorly understood one.

4.2 EPZ FOR THE TEAD STOCKPILE

Following the methodology outlined above, and considering the TEAD stockpile hazard and the distribution of topographic, meteorological, and population resources identified in Sect. 3, we have identified a plausible EPZ for TEAD. To recapitulate, initial concentric circle boundaries are established based on the distribution of credible non-external event accidents and their associated downwind lethal distances; the IRZ concentric circle boundary is based on the accidents occurring under 3 m/s winds and neutral (D) stability, while the PAZ boundary is based on their occurrence under 1 m/s winds and stable (E) conditions. These concentric circle boundaries are then adjusted based on the distribution of topographic, meteorological, and population resources.

For the TEAD stockpile, the largest identified credible non-external event accident is VOMVC 004, a munitions vehicle accident resulting in a fire and causing detonation of VX-filled land mines. As calculated from the D2PC atmospheric dispersion code, the lethal downwind distance under 3 m/s winds and neutral stability is 7.5 km, while its lethal downwind distance under 1 m/s, stable conditions is 32.9 km. Adding 50% to each of these values for uncertainty, they equal approximately 11 and 50 km respectively. Therefore, for TEAD the concentric circle boundary for the IRZ is 11 km and that of the PAZ is 50 km.

As noted in Sect. 3, however, the terrain near TEAD-S would significantly affect the dispersion of agent in the event of a release. The proposed disposal facility is located in the center of Rush Valley and is surrounded by mountain ranges to the west (Onaqui and Stansbury), east (Oquirrh), south (Tintic), and southeast (Thorpe Hills) and by a natural dike to the north(the lesser South Mountains). These mountain ranges separate Tooele Valley from Rush Valley and provide partial barriers to agent dispersion. The South Mountains are particularly important as a partial barrier for diurnal shifts in wind direction; for a moderate to large nighttime accident occurring when slow stable winds are from the south, the agent would tend to move up the Rush Valley until it reached Stockton, where it would concentrate due to obstruction of the South Mountains' natural dike with some agent spilling over into Tooele Valley at lower concentrations. As weather conditions change during daylight , the concentrated agent near Stockton would either move back down the Rush Valley in a wide plume or continue to move into Tooele Valley where it would be dispersed and diluted by winds. If the release were large enough to result in concentrations as far north as the Great Salt Lake, the agent would likely curve around to the east due to wind effects from the lake; it is unlikely, however, that a release could reach Salt Lake City.

Just as a large enough release could result in agent going over and around the South Mountains to the north of TEAD-S, with winds from the north or west it could also leave the Rush Valley to the east-southeast of the installation through Fivemile Pass; in this event, the agent could move into Cedar Valley. In the more unlikely event of winds coming from the east of TEAD-S, agent could move to the west through Johnson Pass or Lookout Pass. It is extremely improbable that agent would move over the Oquirrh Mountains to the east or the Onaqui/Stansbury Mountains to the west. Thus, the three valleys form the basis for establishing planning zones.

4.3. PLANNING ZONES AND DISTANCES

Two types of planning zones are recommended for the TEAD stockpile. The first is the IRZ. Most accident scenarios will be confined in this zone. The second is a PAZ to handle scenarios in which agent is released out of Rush Valley. Due to meteorological conditions and natural feature of the area, it does not make sense to draw arbitrary boundaries to establish the planning zones. Thus, most of the planning zone boundaries are established using natural features of the landscape or other landmarks with which the local populace is familiar (e.g., roads and highways).

A recommended set of boundaries is provided in Figure 4.3. These have been set using mainly valley contours and lake shore-lines. In some places roads or boundaries are used when physical features do not readily define

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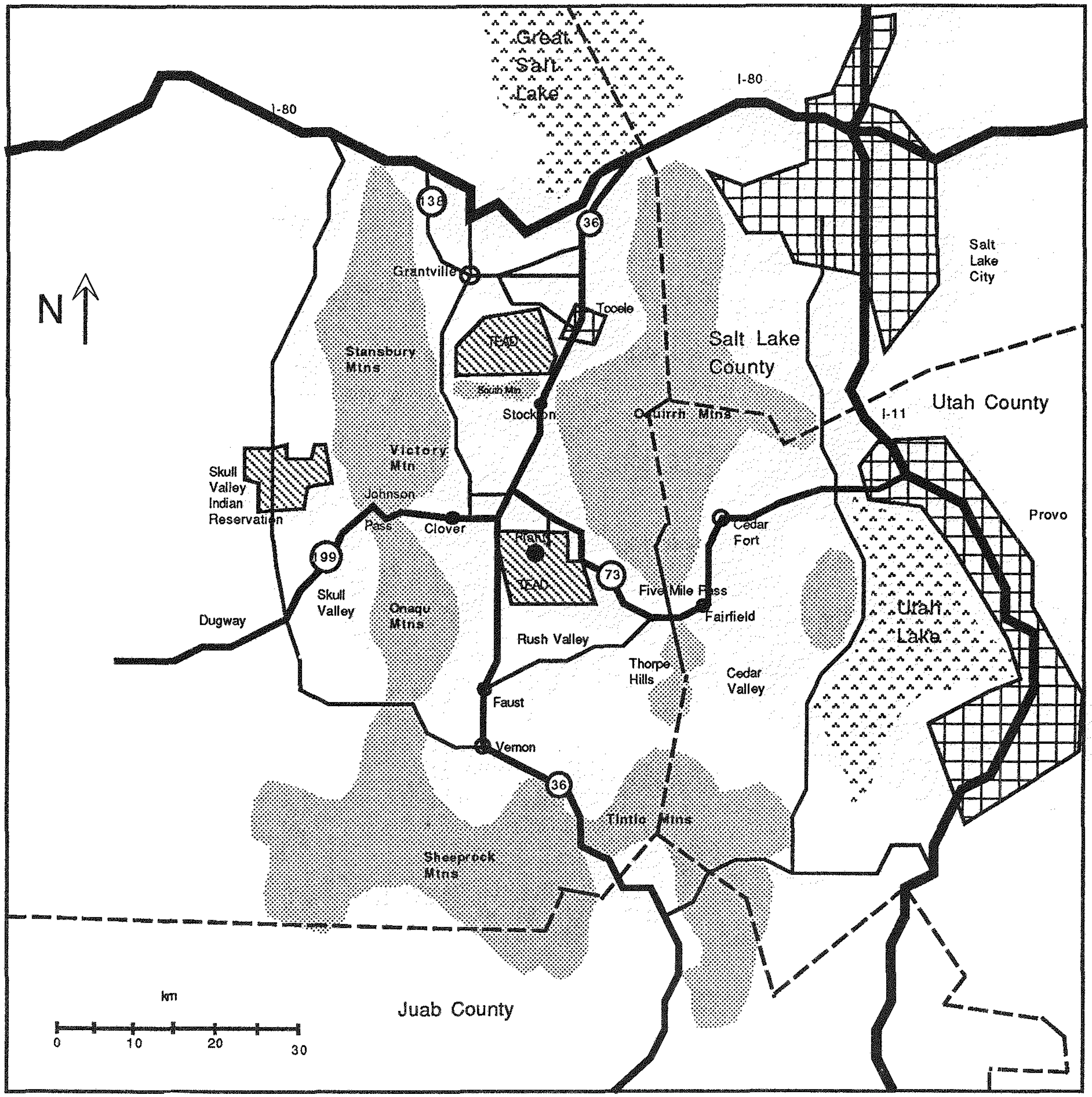

Fig. 4.3. TEAD and vicinity

natural boundaries. Major alternatives to the recommended boundaries include

1. Extending the IRZ to include Vernon to the south because of the population and lack of physical barriers to prevent exposure.
2. Extending the IRZ to include the southern part of Rush Valley to conform to the valley contours.
3. Extending the IRZ to include Fairfield in Cedar Valley because agent would concentrate in the pass.
4. Reducing the IRZ by Victory Mountain north of Johnson Pass to conform to the valley contours.
5. Including part of Skull Valley in the PAZ to handle a rare possibility of agent moving over one of the passes.
6. Reducing the PAZ on the northwest side of Tooele Valley because it is unlikely to be affected due to meteorology.
7. Reducing the PAZ on the northeast side of Tooele Valley to conform to the valley contours (currently drawn on county border).
8. Extending the PAZ to the northeast beyond the Oquirrh Mountains to account for very large energetic releases (if the mountains do not effectively contain the agent's dispersion).

The final determination of emergency planning zone boundaries will be made collectively by affected local governments, state government, the Department of the Army, and the Federal Emergency Management Agency.

5.0 PROTECTIVE ACTIONS

5.1 CATEGORIES OF PROTECTIVE ACTIONS

Based on an ongoing evaluation of the effectiveness of alternative protective actions (Rogers, *et al.* in press), six categories of protective action have been considered for the TEAD concept plan: (a) evacuation, (b) in-place sheltering, (c) respiratory protection, (d) protective clothing, (e) prophylactic drugs, and (f) antidotes. To date, most attention has been paid to protecting potentially exposed persons from inhaled doses; relatively little attention has been paid to skin deposition and ingestion, although skin deposition is certainly an important exposure pathway for mustard and less so for VX (ingestion of potentially contaminated food and water should, of course, be avoided).

Within each of these categories, the various options and their advantages and disadvantages are discussed below. The discussion draws heavily on the forementioned ongoing study and includes the judgments of an expert panel that was asked to evaluate the generic effectiveness of the protective action options. Finally, potentially suitable protective action options for the IRZ and PAZ general publics and institutional populations are identified, and preliminary recommendations are made.

5.1.1 Evacuation

Evacuation involves changing location to avoid exposure, which includes moving by foot or vehicle to an area outside the areas exposed. There are essentially two kinds of evacuations: precautionary, and responsive. Precautionary evacuations involve moving prior to the release of chemicals, and responsive evacuation involve moving after the release of chemicals to avoid exposure.

Of all options, evacuation is the most familiar. When sufficient time is available, it is the best response because it precludes any exposure to chemical agent. In many circumstances, evacuation can be achieved by personal automobile, although transportation may have to be furnished in some cases (e.g., those without cars). The additional capital investment required from all units of government is nil for persons having their own automobiles. Populations without automobiles must be provided with buses or other transportation, or a ride-sharing plan must be implemented and available. The cost of public education/information instructing the population which direction to go and the cost of the requisite warning system have not been considered here.

<u>Description</u>

Evacuation eliminates exposure to chemical agents by removing the potentially exposed person from the area at risk. Although no in-place protective action provides complete (100%) protection under all conditions, evacuation can provide complete protection provided sufficient warning time is available to allow all potentially exposed populations to implement the action. This is most likely to be the case when it is implemented as a precautionary measure. As a responsive measure (i.e., after a release has occurred), it is most likely to be effective for populations farther away from the accident site who have more time to implement the action. Responsive evacuations would not be as effective for nearby populations, particularly for fast-moving releases and plumes. Use

Upon being notified to evacuate, individuals and groups would go to their automobiles or trucks, close the windows and turn off ventilation systems, and drive away from the anticipated lethal plume and possibly to a prearranged assembly point. Evacuees would follow predetermined evacuation routes. Individuals and groups relying on mass transportation (e.g., buses) would assemble at a prearranged location, enter the bus or other vehicle, and be driven to a prearranged mass shelter.

Advantages

1) Evacuation eliminates the possibility of agent exposure.
2) Except for mobility-impaired individuals and institutions, evacuation requires a minimum of public resources.
3) Evacuation requires minimum training and is not intrusive.

Disadvantages

1) Effective evacuation requires extensive evacuation planning.
2) Evacuation can require significant lead time (30 minutes to one hour) and, depending on the accident, may not be effective for individuals living near an accident.

5.1.2 In-Place Sheltering

In-place sheltering involves taking refuge in a structure of various kinds. Five types of sheltering have been identified as of interest for protection from chemical agents. Each is discussed in turn.

5.1.2.1 Normal sheltering

This form of sheltering involves taking refuge in existing buildings prior to exposure for the prevention or mitigation of the amount of exposure. This protective action has been used in the protection of people from radioactive exposures. It has also been used to protect people from toxic chemical releases where small releases occur resulting in small concentrations of toxic in the environment over short durations of time. Normal sheltering is most likely to be effective for chemicals whose effect is proportional to peak concentrations rather than cumulative dose (e.g., ammonia, hydrogen chloride, and hydrogen sulfide).

Description

Normal sheltering can partially block the exposure to chemical agents by reducing the amount of infiltration of airborne agent into the "protected" environment. While no protective action provides complete (100%) protection under all conditions, normal sheltering is thought to be most likely to provide adequate protection under conditions characterized by small releases resulting in relatively low concentrations of agent with limited exposure times (i.e., the plume are fast moving and small).

Use

Normal sheltering involves taking refuge in existing buildings, closing windows and doors, and shutting of ventilation systems that replace indoor air with outdoor air. Once in the sheltered environment people will have to remain calm to promote lowered heart and respiratory rates. In addition, once the concentration of agent is lower in the unprotected environment than in the protected environment people will have to ventilate (i.e., open up) the structure to minimize exposure. Hence, the warning system must not only be able to tell people when to go to shelters of this kind, they must also be capable of telling people when to ventilate.

Advantages

1) Normal sheltering requires only existing resources.
2) Normal sheltering requires no training and no protective equipment, which minimizes the intrusion of protective equipment in the routine environment.
3) Because houses cannot increase the exposure normal sheltering can only increase protection. Furthermore, the median house may be characterized as having approximately 0.7 air changes per hour, which means that the protection factors associated with normal sheltering probably range from around 1.3 to just over ten depending on the cloud passage time (Chester 1988). Hence, normal sheltering provides minimum protection from exposure in situations where emergency actions are precautionary, or concentrations are low, and cloud passage time is limited.
4) Normal sheltering can be implemented quickly. Sorensen (1988) estimates that it can be accomplished in less than ten minutes.
5) Normal sheltering can also serve as a convenient anticipatory step for evacuations by assembling the family unit in one place.

Disadvantages

1) Normal sheltering provides only limited protection, under restricted conditions.
2) If accidents anticipated to result in low concentrations and be of limited duration, become more extensive exposures (i.e., higher concentrations) or more extended exposures, evacuating the expedient shelters in a contaminated environment will have to be accomplished.
3) The "all-clear" requirement is placed on warning systems.

5.1.2.2 Specialized sheltering

This form of sheltering involves taking refuge in commercial tents and structures which are designed explicitly for protection in chemical environments. This protective action is expected to protect people from toxic chemical releases resulting in large concentrations over extended durations (e.g., three to twelve hours).

Description

Special sheltering facilities potentially block the exposure to chemical agents by reducing the amount of infiltration of airborne agent into the "protected" environment. While no protective action provides complete (100%) protection under all conditions, specialized shelters are likely to provide adequate protection under conditions characterized by releases resulting in moderate to large concentrations of agent with exposure times between three to twelve hours (i.e., a slowly travelling plume and the plume of any size).

Use

Special shelters involves taking refuge in facilities created expressly for protection from chemical contamination. To the extent that these shelters may not have televisions, radios or other communication devices, one will have to be obtained for the sheltered area prior to occupation. Once in the sheltered environment people should remain calm to promote lowered heart and respiratory rates.

Advantages

1) Because in-place protection cannot increase the exposure pressurized sheltering can only increase protection. Furthermore, protection factors associated with specialized shelters reduce air infiltration rates, perhaps even to the point of establishing small exhaust rates, which drastically reduces the risks associated with the protective action. This means that the protection factors associated with specialized shelters are likely to be greater than those associated with expedient or enhance sheltering. If air infiltration can be reduced to as few as one change in sixteen hours, the protection factor would range from approximately five to about 120 (Chester 1988). Hence, specialized sheltering provides maximum protection from exposure in nearly all situations.
2) Specialized sheltering can be implemented fairly quickly once the facilities themselves are available. Sorensen (1988) posits if we assume pre-erection or prepositioning of portable shelters of this variety, that movement to a prepared shelter without much preparation time.
3) Specialized sheltering provides maximum protection, under almost all conditions. Hence, pressurized shelters are capable of preventing fatalities when long or continuous releases of agent are anticipated.
4) Specialized sheltering provides shelter for long periods of time and thereby avoid the problems associated with misjudging accident durations and concentrations.

Disadvantages

1) People in specialized shelters may have family members not in the shelter creating distress, conflict and even of breach containment created by people entering or leaving after sealing and pressurization.

2) Specialized sheltering requires that special structures be constructed to provide adequate protection.
3) For most people, specialized shelters require limited attention, however prepositioning or pre-erection would involve a certain amount of intrusion from the emergency action into the routine environment.

5.1.2.3 Expedient sheltering

Expedient sheltering involves taking refuge in existing structures that are tightened against infiltration using common resources and materials, such as plastic bubbles, tape and wet towels. These actions are taken prior to exposure for the prevention or mitigation of the amount of exposure. This protective action is expected to protect people from toxic chemical releases resulting in moderate concentrations over modest durations (e.g., one to three hours).

Description

Expedient sheltering can partially block the exposure to chemical agents by reducing the amount of infiltration of airborne agent into the "protected" environment. While no protective action provides complete (100%) protection under all conditions, expedient sheltering is likely to provide adequate protection under conditions characterized by releases resulting in moderate concentrations of agent with exposure times between one to three hours (i.e., the plume is travelling moderately fast and the plume is of medium size).

Use

Expedient sheltering involves taking refuge in existing buildings, closing windows and doors, shutting of ventilation systems that replace indoor air with outdoor air, taping windows, doors, light sockets and ventilation outlets, and laying a wet towel across the bottom of the door to reduce infiltration. In addition, to the extent that these shelters may not have televisions, radios or other communication devices, one will have to be obtained for the sheltered area prior to occupation. Once in the sheltered environment people should remain calm to promote lowered heart and respiratory rates. In addition, once the concentration of agent is lower in the unprotected environment than in the protected environment people will have to ventilate (i.e., open up) the structure to minimize exposure. Hence, the warning system must not only be able to tell people when to go to shelters of this kind, they must also be capable of telling people when to ventilate.

Advantages

1) Expedient sheltering requires only existing resources, but may be more effective if kits for enhancement, including tape, towels and perhaps a portable radio, are readily available to the people that would have to implement the protective action.
2) Expedient sheltering requires limited training and limited resources, which yields a low level of intrusion of protective equipment in the routine environment.

3) Because expediently sealed structures cannot increase the exposure expedient sheltering can only increase protection. Furthermore, protection factors associated with expedient shelter are increased with the reduction of air infiltration rates. This means that the protection factors associated are likely to be greater than those associated with normal sheltering. If air infiltration can be reduced to one air change in four hours, the protection factor would range from approximately two to about 60 (Chester 1988). Hence, expedient sheltering provides minimum protection from exposure in situations where concentrations are expected to be low to moderate, and cloud passage time is limited in the one to three hour range.
4) Expedient sheltering can be implemented fairly quickly. Sorensen (1988) estimates that taping and sealing an average room can be accomplished in ten to fifteen minutes.

Disadvantages

1) Expedient sheltering provides moderate protection, under conditions where plumes are of limited size. Hence, expedient shelter will not prevent fatalities when long or continuous releases of agent are anticipated.
2) If accidents anticipated to be of limited duration develop into more extended exposures, evacuating the expedient shelters in a contaminated environment will have to be accomplished.
3) The "all-clear" requirement is placed on warning systems.

5.1.2.4 Pressurized sheltering

Pressurized sheltering involves taking refuge in existing structures that are capable of being pressurized to reduce infiltration of toxic vapors. This protective action is expected to protect people from toxic chemical releases resulting in large concentrations over extended durations (e.g., three to twelve hours).

Description

Pressurized sheltering potentially blocks the exposure to chemical agents by reducing the amount of infiltration of airborne agent into the "protected" environment. While no protective action provides complete (100%) protection under all conditions, pressurized sheltering is likely to provide adequate protection under conditions characterized by releases resulting in moderate to large concentrations of agent with exposure times between three to twelve hours (i.e., a slowly travelling plume and the plume of any size).

Use

Pressurized sheltering involves taking refuge in existing buildings, closing windows and doors, shutting of ventilation systems that replace indoor air with unfiltered outdoor air, and starting a pressurization system that uses filtered air to create pressure in the seal structure. In addition, to the extent that these shelters may not have televisions, radios or other communication devices, one will have to be obtained for the sheltered area prior to occupation.

Once in the sheltered environment people should remain calm to promote lowered heart and respiratory rates.

Advantages

1) Pressurized sheltering requires only that existing structures be augmented by pressurization systems.
2) For most people, pressurized shelters require limited attention which yields a low level of intrusion of protective equipment in the routine environment.
3) Because in-place protection cannot increase the exposure pressurized sheltering can only increase protection. Furthermore, protection factors associated with pressurized shelters reduce air infiltration rates, perhaps even to the point of establishing small exhaust rates, which drastically reduces the risks associated with the protective action. This means that the protection factors associated with pressurized shelters are likely to be greater than those associated with expedient or enhance sheltering. If air infiltration can be reduced to as few as one change in sixteen hours, the protection factor would range from approximately five to about 120 (Chester 1988). Hence, pressurized sheltering provides maximum protection from exposure in nearly all situations.
4) Pressurized sheltering can be implemented fairly quickly. Sorensen (1988) estimates that activating an existing pressure system will take about five minutes.
5) Pressurized sheltering provides maximum protection, under almost all conditions. Hence, pressurized shelters are capable of preventing fatalities when long or continuous releases of agent are anticipated.
6) Pressurized sheltering provides shelter for long periods of time and thereby avoid the problems associated with misjudging accident durations and concentrations.

Disadvantages

1) People in pressurized shelters may have family members not in the shelter creating distress, conflict and even of breach containment created by people entering or leaving after pressurization.

5.1.2.5 Enhanced sheltering

Enhanced sheltering involves taking refuge in structures in which infiltration has been reduced via weatherization techniques. This protective action is expected to protect people from toxic chemical releases resulting in moderate concentrations over modest durations (e.g., one to three hours).

Description

Enhanced sheltering can partially block the exposure to chemical agents by reducing the amount of infiltration of airborne agent into the "protected" environment. While no protective action provides complete (100%) protection under all conditions, enhanced sheltering is likely to provide adequate protection under conditions characterized by releases resulting in moderate concentrations of agent with maximum exposure times between one to three hours (i.e., the plume is travelling moderately fast and the plume is of medium size).Use

Enhanced sheltering involves taking refuge in existing weatherized buildings, which have reduced infiltration rates for energy efficiency, closing windows and doors, shutting of ventilation systems that replace indoor air with outdoor air. In addition, to the extent that these shelters may not have televisions, radios or other communication devices, one will have to be obtained for the sheltered area prior to occupation. Once in the sheltered environment people should remain calm to promote lowered heart and respiratory rates. In addition, once the concentration of agent is lower in the unprotected environment than in the protected environment people will have to ventilate (i.e., open up) the structure to minimize exposure. Hence, the warning system must not only be able to tell people when to go to shelters of this kind, they must also be capable of telling people when to ventilate.

Advantages

1) Enhanced sheltering requires existing resources be enhanced much the same way that they would be for energy conservation.
2) Enhanced sheltering requires limited training and limited additional resources, and for most people would not be recognizable as different from a routine environment. This means that a low level of intrusion of protective equipment in the routine environment is associated with this protective action.
3) Because in-place sheltering cannot increase the exposure enhanced sheltering can only increase protection. Furthermore, protection factors associated with enhanced sheltering are increased with the reduction of air infiltration rates. This means that the protection factors associated are likely to be greater than those associated with normal sheltering. If air infiltration can be reduced to an air change in four hours, the protection factor would range from approximately two to about 60 (Chester 1988). Hence, expedient sheltering provides limited protection from exposure in situations where concentrations are expected to be low to moderate, and cloud passage time is limited in the one to three hour range.
4) Enhanced sheltering can be implemented very quickly. Sorensen(1988) estimates that the required action could be accomplished in less than ten minutes.

Disadvantages

1) Enhanced sheltering provides moderate protection, under conditions where plumes are of limited size. Hence, expedient shelter will not prevent fatalities when long or continuous releases of agent are anticipated.
2) If accidents anticipated to be of limited duration develop into more extended exposures, evacuating the expedient shelters in a contaminated environment will have to be accomplished.
3) The "all-clear" requirement is placed on warning systems.

5.1.3 Respiratory Protection

Respiratory protection provides non-contaminated air for inhalation in potentially contaminated environments. This involves either using protective devices that remove airborne chemicals, aerosols, and vapors from the air prior to inhalation, or the direct introduction of non-contaminated air for inhalation. Six types of respiratory protection have been identified as of interest in providing protection from chemical agents.

5.1.3.1 Gas masks

Gas masks with filters or filtering materials remove airborne toxics prior to inhalation. A wide variety of masks are available commercially, with most being targeted at industrial users.

Description

The full face mask is comprised of a face covering shield connected to a filter or filter cartridge. Full face mask are typically regulated to maintain unidirectional air flow through the filters. By covering the whole face the full face masks are designed to keep the eyes, nose and mouth clear of contamination. Chester (1988) estimates that full face masks are capable of providing a respiratory protection factor of about 2000. However, the limiting factor with full face masks, as with other masks, is the integrity of the seal between the mask and the face.

Use

Using the full face mask involves retrieving the device from its storage location, extracting it from its storage container, placing on the face, and strapping in place. While a full face mask may take as much as ten minutes to implement, Sorensen (1988) estimates that with training it can be implemented in as little as one minute once it is located. The full face mask is very likely to provide respiratory protection from low to moderate concentrations, but may also be used for larger doses while people pursue other protection (e.g., while evacuating, or on the way to shelter).

Advantages

1) While the full face mask is storable, it is not easily stored which means that it is probably more obtrusive than many other respiratory devices.
2) The full face mask can be implemented in as little as a minute once it is located, this implementation time will require moderate training and considerable practice.
3) The full face mask provides a high degree of respiratory protection.
4) The full face mask requires little physical effort or mental concentration to maintain seal between face and mask once it is in use.

Disadvantages

1) The full face mask requires considerable training and practice to assure proper use in emergencies.

2) The full face mask would require that the individual have the device, be able to retrieve it, and know how to use it in the event of an accident.
3) The full face mask would not protect guests and visitors that would not have similar respiratory protection.
4) The full face mask is one of the most obtrusive devices among the respiratory protection devices, its distribution to the public is likely to raise awareness of the program, and could significantly contribute to public concern.

5.1.3.2 Hoods

Hoods with fan-driven filters may be placed over the head and sealed at the waist and wrists to remove contaminated air prior to inhalation.

Description

Hoods are comprised of a protective covering ventilated through fan-driven filters, which are placed over the head and sealed at the waist and wrists. They are typically used for respiratory protection for children or when the size or shape of the face makes maintaining the integrity of the seal between face and mask nearly impossible. Hood like full face masks are typically regulated to maintain unidirectional air flow through the filters. By covering the whole head and upper body hoods are designed to keep the eyes, nose and mouth clear of contamination, as well as affording protection of the upper body from disposition. It is anticipated that hoods, like masks, are capable of providing a respiratory protection factor of about 2000. The limiting factor with hoods is the integrity of the seal between the hood and the waist and wrists.

Use

Using hoods involves retrieving the device from its storage location, extracting it from its storage container, placing it over the head, securing the waist and wrists and starting the fan-driven filtered ventilation. While a hood may take as much as ten minutes to implement, it seems reasonable to estimate that with training implementation time can be reduced to as little as a three to five minutes once it is located. The limiting factor for time to implement seems to be the ability to "dress" children in the hoods. Hoods are very likely to provide respiratory protection from low to moderate concentrations, but may also be used for larger doses while people pursue other protection (e.g., while evacuating, or on the way to shelter).

Advantages

1) While hoods are storable, it is not easily stored which means that it is probably more obtrusive than many other respiratory devices.
2) Hoods can be implemented in as little as a few minutes once they are located, this implementation time will require moderate training and practice.
3) Hoods provide a high degree of respiratory protection.
4) Hoods require almost no physical effort or mental concentration to maintain seal between waist and wrists and the hood once they are in use.

Disadvantages

1) Hoods require some training and practice to assure proper use in emergencies.
2) Hoods would require that the individual have the device, be able to retrieve it, and know how to use it in the event of an accident.
3) Hoods would not protect guests and visitors that would not have similar respiratory protection.
4) Hoods are one of the most obtrusive devices among the respiratory protection devices, their distribution to the public is likely to raise awareness of the program, and could significantly contribute to public concern.

5.1.3.3 Bubbles

Bubbles are sealable containers with a fan-driven filter that place the entire person in the protected environment. They are typically used for protection of infants and toddlers.

Description

Bags are protective enclosures that are usually used to protect infants and toddlers. These protective enclosures are comprised of a protective covering ventilated through either battery operated fan-driven filters or by being connected to an adult's protection which draws air through the filter into the infant protection area. By covering the child's whole body protection bubbles are designed to keep the eyes, nose and mouth clear of contamination, as well as affording protection of the body from disposition. It is anticipated that protection bubbles like hoods are capable of providing a respiratory protection factor of about 2000.

Use

Using the fan-driven protection bubbles involves retrieving the device from its storage location, extracting it from its storage container, placing the infant or toddler in the enclosed environment, and starting the fan-driven filtered ventilation. While using the adult-ventilated protection bubble involves all of those steps plus the steps required for the adult to don their protection. While a protection bubble may take as much as fifteen minutes to implement, it seems reasonable to estimate that with training implementation time can be reduced to as little as five to ten minutes once it is located. Protection bubbles are very likely to provide respiratory protection from low to moderate concentrations, but may also be used for larger doses while people pursue other protection (e.g., while evacuating, or on the way to shelter).

Advantages

1) Protection bubbles can be implemented in as little as a five to ten minutes once they are located, this implementation time will require moderate training and practice.
2) Protection bubbles provide a high degree of respiratory protection.

3) Protection bubbles require no physical effort or mental concentration to maintain seals as they are whole body enclosures.

Disadvantages

1) While protection bubbles are storable, it is not easily stored which means that it is probably more obtrusive than many other respiratory devices.
2) Protection bubbles require some training and practice to assure proper use in emergencies.
3) Protection bubbles would require that the individual have the device, be able to retrieve it, and know how to use it in the event of an accident.
4) Protection bubbles would not protect guests and visitors that would not have similar respiratory protection.
5) Protection bubbles are one of the most obtrusive devices among the respiratory protection devices, their distribution to the public is likely to raise awareness of the program, and could significantly contribute to public concern.

5.1.3.4 Mouthpiece respirators

Mouthpiece respirators are small tubes with filter material inserted into the mouth to remove contamination prior to inhalation through the mouth.

Description

The mouthpiece respirator is simply comprised of a mouthpiece connected to a filter cartridge by a tube. Respiration is limited to the mouth by a nose clip. To gain maximum protection offered by this device the user could don a transparent hood (e.g., a plastic bubble) and exhale through the nose, which would flush the hood with uncontaminated air. This would help keep the eyes clear of contamination. This device is intended to be used only for a few minutes, while the wearer is pursues other protective actions (e.g., evacuation, or sheltering). However, the limiting factor with the mouthpiece respirator is the integrity of the seal between the lips and the mouthpiece.

Use

Using the mouthpiece respirator involves retrieving the device from its storage location, insert the respirator in the mouth and clip the nose or cover the head with a transparent hood. The simplicity of the device makes it possible to use this device without training. Chester (1988) estimates that it can be implemented by the untrained user very rapidly, probably in under a minute once it is located. The mouthpiece respirator requires considerable physical effort and a fair amount of mental concentration to maintain the seal between the lips and mouthpiece. The mouthpiece respirator is most likely to provide reasonable respiratory protection from low to moderate concentrations while people are pursuing other protection (e.g., while evacuating, or on the way to shelter).

Advantages

1) The mouthpiece respirator is storable, which means that it is probably less obtrusive than many other respiratory devices.
2) The mouthpiece respirator can be implemented in only a few seconds, once it is located.
3) The mouthpiece respirator provides moderate respiratory protection.
4) The mouthpiece respirator requires no training for adequate use.

Disadvantages

1) The mouthpiece respirator requires considerable physical effort and mental concentration to maintain seal around mouthpiece.
2) Augmenting the mouthpiece respirator to achieve eye protection requires some dexterity and concentration, which likely to be difficult for people in the process of pursuing other protective actions.
3) The mouth piece respirator would require that the individual have the device, and be able to retrieve it in the event of an accident.
4) The mouthpiece respirator would not protect guests and visitors that would not have similar respiratory protection.
5) The mouthpiece respirator would have to be replaced by a mask if durations of potential exposure increased to more than an hour.
6) While the mouthpiece respirator is one of the least obtrusive devices among the respiratory protection devices, its distribution to the public is likely to raise awareness of the program, and could significantly contribute to public concern.

5.1.3.5 Facelet mask

The facelet mask involves covering of the nose and mouth with a charcoal filter cloth expressly designed for use in respiratory protection from toxic chemical.

Description

Developed by the British, the facelet mask is comprised of a charcoal cloth manufactured by pyrolizing and steam activating rayon material. It is held on the face covering the mouth and nose by elastic straps. Chester (1988) estimates it would yield a respiratory protection factor of 1200 against GB, and 80 against mustard. However, the limiting factor with the facelet mask, as with other masks is the integrity of the seal between the mask and the face, which would probably limit the protection factor to under a 1000.

Use

Using the facelet mask involves retrieving the device from its storage location, extracting the mask and its straps from their package, determining how to attach the straps and putting on the mask. While with some limited training and practice the mask might be put on over the nose and mouth quite quickly and held in place with a hand, Chester (1988) estimates that it is likely to take a few minutes to don the facelet mask. The facelet mask is most likely to provide reasonable respiratory protection from low to moderate concentrations while people are pursuing other protection (e.g., while evacuating, or on the way to shelter).

Advantages

1) The facelet mask is very storable, which means that it is probably the least intrusive respiratory device, because it can be stored unobtrusively.
2) The facelet mask can be implemented quite quickly, probably in less than a few minutes.
3) The facelet mask provides moderate respiratory protection from agents GB and mustard.

Disadvantages

1) Using the facelet mask tends to give a sensation of recycling a lot of warm, damp, stale air, which makes it less comfortable to use and to the extent that the mask would becomes saturated with moisture, the absorption capacity would be reduced.
2) The facelet mask would require that the individual have the mask, be trained in its use, and be able to retrieve it in the event of an accident.
3)The facelet masks would not protect guests and visitors that would not have similar respiratory protection.
4) While the facelet mask is one of the least obtrusive devices among the respiratory protection devices, it distribution to the public is likely to raise awareness of the program, and could significantly contribute to public concern.

5.1.3.6 Expedient respiratory protection

Expedient respiratory protection involves placing a wet cloth over the nose and mouth to remove contamination prior to inhalation.

Description

Expedient respiratory protection involves the use of available resources for limited gains in protection against airborne chemicals. A wet thick cloth (e.g., a wash cloth) is held on the face covering the mouth and nose with a hand. Expedient measure such as this are limited both by their ability to remove contamination from the area and the ability to maintain the integrity of the cover over the nose and mouth.

Use

Using expedient measure of this variety involves gathering the resources required to implement the action, wetting the cloth and placing it over the nose and mouth. No training is required for these kinds of measures to be implemented very quickly. Sorensen(1988) estimates that expedient measure can be implement in a few seconds. Expedient respiratory protection measures are only likely to provide any respiratory protection from relatively small concentrations while people are pursuing other protection (e.g., while evacuating, or on the way to shelter).

Advantages

1) Expedient respiratory protection is completely unobtrusive.
2) Expedient respiratory protection can be implemented very rapidly probably in as little as a few seconds.
3) Expedient measures would protect guests and visitors.
4) Expedient respiratory protection provides limited protection from low concentrations for very short durations, probably under fifteen minutes.

Disadvantages

1) Expedient respiratory protection provides no protection for either moderate or high concentrations, or durations longer than a few minutes.
2) Expedient respiratory measures may be difficult to maintain while pursuing other protective actions (e.g. evacuation driving a vehicle).

5.1.3.7 Self contained breathing apparatus

Self contained breathing apparatus (SCBA) provides non-contaminated air for inhalation.

Description

SCBA supply bottled air directly to the individual using it for respiratory protection. They are comprised of a tank or bottle of non-contaminated air, attached through a regulator to either a mouthpiece or a full face mask. SCBA equipment that covers the whole face are designed to keep the eyes, nose and mouth clear of contamination. SCBA are capable of providing respiratory protection for duration directly dependent on the amount of air in the bottle and the rate of respiration. The limiting factor with SCBA covering the face, as with other masks, is the integrity of the seal between the mask and the face, while mouthpiece SCBA are limited by the seal between the mouthpiece and the lips.

Use

Using SCBA involves retrieving the device from its storage location, extracting it from its storage container, placing the mask on the face or the mouthpiece in the mouth, and turning it on. While a full face SCBA may take as much as ten minutes to implement, like full face masks, training can reduce implementation times to as little as 1 minute once the SCBA equipment is located. SCBA equipment is very likely to provide respiratory protection from moderate to high concentrations, but because of it limited duration of protection it is most likely to be useful for people pursuing other protection (e.g., while evacuating, or on the way to shelter).

Advantages

1) While SCBA is storable, it is not easily stored which means that it is probably more obtrusive than many other respiratory devices.
2) SCBA can be implemented in as little as a minute once it is located, this implementation time will require moderate training and practice.

3) SCBA provides a high degree of respiratory protection.
4) Face covering SCBA requires little physical effort or mental concentration to maintain seal between face and mask once it is in use.
5) Some people may have SCBA equipment specifically designed for underwater use, which could be used for respiratory protection from chemical agents.

<u>Disadvantages</u>

1) SCBA requires some training and practice to assure proper use in emergencies.
2) SCBA would require that the individual have the device, be able to retrieve it, and know how to use it in the event of an accident.
3) SCBA would not protect guests and visitors that would not have similar respiratory protection.
4) SCBA is very a obtrusive device for respiratory protection, its distribution to the public is likely to raise awareness of the program, and could significantly contribute to public concern.
5) Mouthpiece SCBA requires considerable physical effort or mental concentration to maintain seal between face and mask once it is in use.

5.1.4 Protective Clothing

Protective clothing involves covering the body to avoid the disposition of chemicals on the skin. Since skin deposition is a potentially significant pathway for mustard exposures, reducing the possibility of such exposure with protective clothing is especially important. Two types of protective clothing are of potential interest for protection from chemical agent.

5.1.4.1 <u>Special protective clothing</u>

Special protective clothing is designed expressly for the purpose of protection from skin deposition. Protective clothing can partially block exposure to chemical agents by preventing the deposition of agent on the skin.

<u>Description</u>

Special protective clothing is comprised of clothing made of special fabrics to reduce the deposition of chemical agent on the skin. Special protective clothing prevents agent from becoming deposited on the skin by covering the whole head, upper body, arms, legs, feet and hands with fabric specifically design to prevent penetration of droplets of agent. The limiting factor with special protective clothing is the ability to keep all skin covered to prevent skin contact. Special protective clothing is likely to provide skin deposition protection under conditions characterized by releases resulting in moderate concentrations of agent with exposure times between 1 to 3 hours (i.e., the plume is travelling moderately fast and the plume is of medium size).

Use

Special protective clothing involves donning specialized suits to protect against exposing skin to agent. While specialized clothing can be used to protect against dermal exposures, protective clothing does not protect people from inhalation and ingestion exposures. It is reasonable to estimate that donning protective clothing will require slightly more time than getting dressed. Sorensen (1988) estimates that special protective clothing will take between five and ten minutes depending on its complexity. Using specialized protective clothing involves retrieving them from their storage location, extracting from its storage container, putting it on, an check all seams between pieces for potential exposures. While a protective clothing may take as much as ten minutes to implement, it seems reasonable to estimate that with training implementation time can be reduced to as little as a three to five minutes once they are located. Protective clothing is very likely to provide dermal protection from low to moderate concentrations, and may even provide limited protection for larger doses while people pursue other protection (e.g., while evacuating, or on the way to shelter).

Advantages

1) While protective clothing easily stored, it is fairly obtrusive.
2) Protective clothing can be implemented in as little as three to five minutes once they are located, this implementation time will require some training and practice.
3) Protective clothing provides a high degree of dermal protection.

Disadvantages

1) Protective clothing requires some training and practice to assure proper use in emergencies.
2) Protective clothing would require that the individual have the device, be able to retrieve it, and know how to use it in the event of an accident.
3) Specialized protective clothing would not protect guests and visitors that would not have similar respiratory protection.
4) Specialized protective clothing is very obtrusive, its distribution to the public is likely to raise awareness of the program, and could significantly contribute to public concern.

5.1.4.2 Expedient protective clothing

Expedient protective clothing which involves using available clothing to protect people from skin deposition. Expedient protective clothing can partially block exposure to chemical agents by preventing the deposition of agent on the skin.

Description

Expedient protective clothing is comprise of regular clothing, put on to protect the wearer form deposits of agent on the skin. Expedient protective clothing covers the whole head, upper body, arms, legs, feet and hands with layers of fabric and can include using rain gear to prevent droplets of agent from depositing on the skin. Expedient protective clothing is limited both by its ability to prevent penetration and keep all skin covered to prevent skin contact. Expedient protective clothing is likely to provide skin deposition protection under conditions characterized by releases resulting in low concentrations of agent with exposure times under an hour (i.e., a fast moving plume and of small to medium size).

Use

Expedient protective clothing involves dressing in layers of winter clothing with long sleeves and long pants, and protecting the head, and neck with a hood or draped towel, and protecting hands with gloves, to prevent exposing skin to agent. To the extent possible the outermost layer of expedient clothing should be moisture resistant to help prevent penetration. While expedient clothing can provide limited protection against dermal exposures, protective clothing does not protect people from inhalation and ingestion exposures. It is reasonable to estimate that donning expedient protective clothing will require slightly more time than getting dressed. Sorensen (1988) estimates that protective clothing will take between five and ten minutes depending on its complexity, expedient protective clothing is not anticipated to be very complex and thereby implementation times are expected to be as little as five minutes.

Advantages

1) Expedient protective clothing is completely unobtrusive.
2) Expedient protective clothing can be implemented in as little as five to ten minutes once they are located, this implementation time requires little or no training and practice.
3) Expedient protective clothing provides a moderate degree of dermal protection for low concentrations for relatively short durations.
4) Expedient protective clothing would use available resources to protect guests and visitors just as it would residents.

Disadvantages

1) Expedient protective clothing would require that the individual gather readily available resources, decide how to use them most effectively and use them to protect themselves and their family in the event of an accident.
2) Expedient protective clothing can only protect against dermal exposure.
3) Expedient protective clothing provides limited protection against low to moderate concentrations and probably does not protect against dermal exposures for higher concentrations over extended periods.

5.1.5 Prophylactic Drugs

Prophylactic drugs are used prior to agent exposure for the prevention or mitigation of agent effects. This protective action has been seriously considered only for potential nerve agent exposure. The Center for Environmental Health and Injury Control of the Centers for Disease Control of the Department of Health and Human Services has recommended that this protective action be eliminated from use except by trained or emergency and medical personnel (e.g., emergency medical technicians, medical doctors, and registered nurses). We concur with this recommendation.

Description

Pretreatment by drugs that can partially block the effects of these agents on the nervous system offer some degree of protection from incapacitation or death; none provide 100% protection for an unlimited period of time. These findings are largely based on laboratory studies with guinea pigs.

Use

Drugs tested for their pretreatment efficacy include combinations of pralidoxime mesylate, atropine, Valium, pyridostigmine, physostigmine and aprophen. A combination of pralidoxime mesylate and atropine is available as an autoinjector unit in the United Kingdom (U.K.) and is approved for pretreatment use by Commonwealth military personnel. The U.K. protocol calls for oral self-administration of Valium at the time of intramuscular injection. This combined approach has been successfully tested in guinea pigs exposed to lethal concentrations of either Agent GB or Agent VX, but is not currently approved for use in the U.S. To our knowledge, physostigmine has not been approved for human pretreatment in either the U.S. or U.K.

Compounds considered for pretreatment use are powerful drugs that have toxic properties of their own. Protective doses need to be determined by trained individuals on the basis of body weight and condition of health. In unskilled hands, damaging doses could easily be administered (children or individuals weakened by age or illness are vulnerable here). There is an additional concern of substance abuse if uncontrolled access to these drugs were permitted.

Advantages

1) Pretreatment by prophylactic drugs has been shown to be an effective protection against incapacitation or death induced by exposure to the lethal nerve agents GB and VX.
2) The additional protection offered by prophylactic drugs (in addition to the presumed use of protective equipment) would be an advantage to emergency personnel responsible for transporting victims out of a contaminated area, providing medical support to contaminated victims, or providing medical support in a contaminated area.
3) Individuals whose jobs required frequent trips into contaminated or potentially contaminated areas(such as police officers, fire fighters, repair crews, etc.), would also benefit.

Disadvantages

1) Drug storage can be a problem. Some prophylactic compounds require controlled storage conditions and may deteriorate if these conditions are not upheld. Rotation of stocks is necessary to maintain drug potency.
2) Potential for substance abuse and accidental poisoning. Valium is a controlled substance and atropine is a hallucinogen.

3) Recommended drugs are powerful and can cause serious injury if mishandled.
4) Need for trained personnel to provide treatment.

5.1.6 Antidotes

Antidotes are used to relieve, prevent, or otherwise counteract adverse effects resulting from agent exposure. Antidotes are somewhat agent-specific in that nerve agents (as a group) require different antidotes than the vesicants. The Center for Environmental Health and Injury Control of the Centers for Disease Control of the Department of Health and Human Services has recommended that this protective action be eliminated from use except by trained or emergency and medical personnel (e.g., emergency medical technicians, medical doctors, and registered nurses). We concur with this recommendation.

Description

Nerve agent antidotes (atropine, pralidoxime, other oximes) block the effects of agent-induced skeletal and smooth muscle contraction (relieve convulsions and loss of breathing control) and reduce glandular paralysis (dries up the copious respiratory secretions that make normal breathing difficult). These same antidotes are effective in treating cases of organophosphate insecticide poisoning (e.g., Parathion, Malathion) and the treatment protocols are based on sound clinical data for humans.

There are no specific antidotes for mustard agent poisoning; its chemical reaction with biological tissue is so rapid as to be irreversible for all practical purposes. Attempts at therapy have been aimed at rapid decontamination and symptomatic therapy to relieve the effects of chemical burns to the skin, eyes and respiratory tract.

Exposure to the organic arsenical vesicant, Lewisite, can be effectively countered by treatment with British anti-lewisite (BAL) after untreated time lapses of as much as one hour. BAL was developed immediately prior to World War II. Newer, water-soluble BAL analogues can be administered orally or by intravenous drip, are effective in laboratory animals even if provided four hours post-exposure, and have been successful in treating occupational victims of heavy-metal (e.g., methylmercury, lead) poisoning. Dosage and treatment protocols for the BAL analogues have not yet been developed in the U.S. because these compounds are considered "orphan drugs."

Use

Combined therapy using intramuscular or intravenous treatment with atropine plus pralidoxime is more effective for treating nerve agent exposure than either antidote used in isolation. Both drugs are available as autoinjector units to U.S. military personnel. Effective dose is primarily based on victim body weight, age, and severity of observed agent effect(s). Careful monitoring is necessary to maintain adequate dose rate while simultaneously managing signs of antidote overdose (elevated body temperature and blood pressure, restlessness, hallucinations, etc.). In severe cases, extended treatment over days or weeks may be necessary to counteract the effects of continual organophosphate mobilization from body storage. Other oximes, alone or in combination with Valium ,atropine and benactyzine are part of the antidote treatment regimes in use by military services in the U.K. and Europe.

Instantaneous removal of mustard from body surfaces is the best form of protection. One way to accomplish this is by washing with soap and water. According to one recent study (van Hooidonk, et al. 1983) various household products (e.g., tissue paper, flour, talcum powder, washing abrasive, and salad oil) were effective in removing mustard from guinea pig skin, although their effectiveness requires immediate application (e.g., within 4 min). The most effective treatment was sprinkling flour on the contaminated skin, followed by removal of the flour with wet tissue paper. Wet tissue paper alone simply spread the mustard over a larger skin surface, suggesting that washing with water needs to be combined with detergent use or some other solubilizer or adsorber of mustard. Attempts at therapy of mustard poisoning have generally been aimed at rapid decontamination and symptomatic (i.e., treatment of mustard-induced symptoms) therapy.

In the case of battlefield exposure, Army documents (U.S. Army 1974, 1975) emphasize the immediate decontamination following exposure. Copious flushing with water is recommended for eye contamination. Fuller's earth powder (which is used to adsorb liquid agent droplets) and chloramine powder (which reacts chemically with mustard) are effective skin decontaminants and are supplied to military personnel in field kits. A protective ointment, known as "M5" and supplied to field personnel, contains chloramide S-330, which can function both as a decontaminant and a protective barrier (Koslow 1987).

Repeated intramuscular injections of BAL are usually needed to treat the topical and systemic effects of lewisite. Effective doses are, again, based on victim body weight, age and severity of effect(s). BAL is not likely to be fatal at clinical doses, but a consistent response in BAL-treated patients is a rise in diastolic/systolic blood pressure as well as rapid heartbeat. Nausea and headache are often noted and children may experience fever. Treatment should be carefully monitored by trained personnel.

Advantages

1) Appropriate use of decontaminants may save lives and reduces the severity of effects from sublethal doses.
2) Decontaminant does not usually generate disabling side effects.
3) Effective treatment can be performed under field conditions.
4) Given the carcinogenicity of mustard agent, prompt decontamination is recommended to reduce the dose to avoid latent (i.e., carcinogenic) as well as acute effects.

Disadvantages

1) Some antidote drugs require controlled storage conditions and may deteriorate if these conditions are not upheld. Rotation of stocks is necessary to maintain drug potency.
2) Potential for substance abuse and accidental poisoning (valium is a controlled substance and atropine is a hallucinogen).

3) Recommended drugs are powerful and can cause serious injury if mishandled.
4) Need for trained personnel to provide treatment.
5) Potential adverse effects of antidote treatment by individuals unlicensed to administer drugs is governed by "Good Samaritan" laws specific to each state. Great variability exists in the authority and protection (from lawsuit) offered to unlicensed individuals such as teachers and first aid volunteers.
6) BAL treatment is of limited utility; the sole stockpile of lewisite is reported to be comparatively small and resides at one site--the Tooele Army Depot in Utah.
7) There are no known disadvantages of decontaminating when mustard exposure is suspected.

5.2 COMBINATIONS OF PROTECTIVE ACTIONS

In addition to the individual protective actions discussed above, it is obviously possible and desirable to combine different protective actions into a single strategy if doing so enhances overall effectiveness and survivability. Such an approach combines the advantages of different options in an attempt to obviate the disadvantage(s) of each. The most obvious combinations include some form of respiratory protection (e.g., gas mask, mouthpiece respirator, bubble, or hood) with either evacuation or some form of sheltering. Although only two basic options are discussed below, a combination of protective clothing with either of these two should also be considered for the TEAD stockpile for those releases involving mustard and, possibly, VX agent.

5.2.1 Evacuate with Respiratory Protection

It is possible that the effectiveness of evacuation might be enhanced by providing respiratory protection during its implementation. If one can reduce or eliminate deposition and ingestion exposure pathways (e.g., being in an evacuating vehicle) and similarly reduce an inhaled dose (by use of respiratory protection), the overall effectiveness of the evacuation should be improved.

5.2.2 Shelter with Respiratory Protection

Sheltering may also be made more effective by some form of respiratory protection. Some protective devices (e.g., mouthpiece respirators) may be used in acquiring safe access to an enhanced or expedient shelter. Other respiratory devices (e.g., gas mask, bubble, or hood) would decrease total dose within an enhanced or expedient shelter. Such an approach may be particularly appropriate for continuous or longer-term releases where the protection afforded by shelter alone (one to three hours; see Sect. 5.1) may be inadequate.

5.3 PRELIMINARY EVALUATION OF PROTECTIVE ACTIONS

In support of the ongoing protective action effectiveness support study (Rogers, *et al.*, in press), a panel of experts[1] was assembled early in CY 1989 to identify evaluative criteria and apply those criteria to various protective actions, including evacuation, sheltering, and respiratory protection. The panel's composition was based on the the notion of obtaining comprehensiveness with respect to the physical characteristics of each protective action option, the option's effectiveness with respect to mitigating adverse health effects, and the personal and organizational aspects of the option's implementation. Although it is beyond the scope of this document to report on the results of that exercise in detail, the following discussion identifies the criteria and the panel's evaluation of those actions.

5.3.1 Evaluative Criteria

The panel identified a variety of criteria for evaluating protective action options. These criteria were subsequently grouped according to whether the criterion related to 1) the level of safety provided by the option, 2) the requirements for implementing the option effectively, and 3) the option's level of intrusiveness in the family and community or other relevant level of social organization. Since different factors were deemed important among these three categories for the three different kinds of protective actions (evacuation, sheltering, and respiratory protection), the specific criteria for the categorically different protective action options were different (see Figs. 5.1 and 5.2).

5.3.2 Protective Action Option Evaluation

The summary results of the evaluation are presented in Fig. 5.1 and 5.2. For each evaluation criterion, each panel member ranked each protective action option on a scale from least desirable to most desirable. These scores were averaged for each protective action option. These averaged scores are presented in Figs. 5.1 and 5.2.

5.4 PROTECTIVE ACTION OPTIONS FOR TEAD

With the proper warning system and command and control system, the potential protective action options at TEAD for various subgroups of the general population are summarized in Tables 5.1 and 5.2. Results of the protective action effectiveness support study may alter these

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[1] These individuals included Amnon Birenzvige of the U.S. Army Chemical Research, Development and Engineering Center, Aberdeen Proving Ground, MD; Michael Lindell, Department of Psychology, Michigan State University, East Lansing, MI; Dennis Mileti, Director, Hazards Assessment Laboratory, Colorado State University, Fort Collins, CO; and Frederick Sidell, MD, U.S. Army Medical Research Institute of Chemical Defense, Aberdeen Proving Ground, MD. Their fields of expertise are physical means of protection from chemical agent exposure, individual response to disasters, organizational response to disasters, and the health effects of chemical agent exposure, respectively.

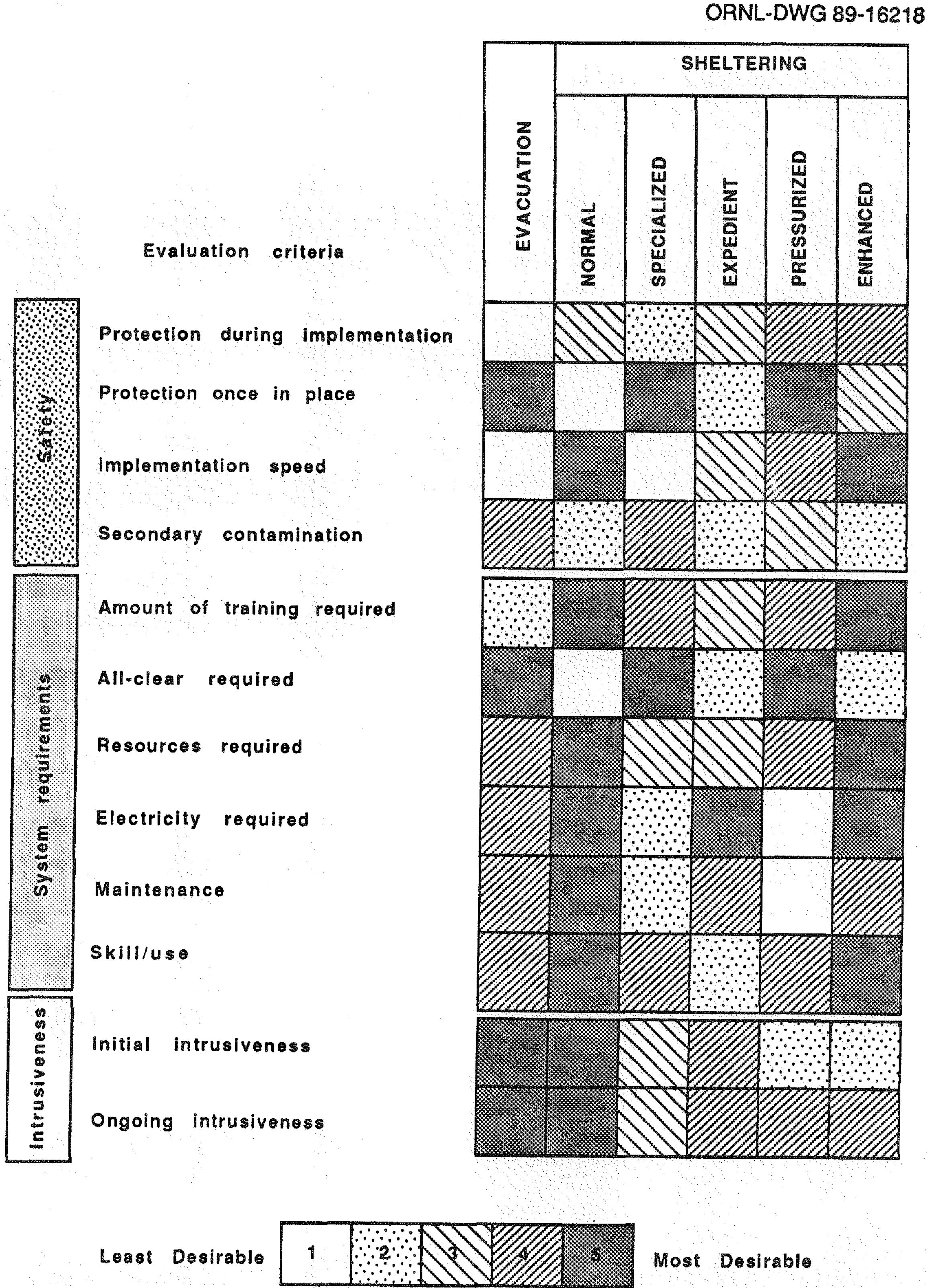

Fig. 5.1. Expert panel evaluation of evacuation and sheltering.

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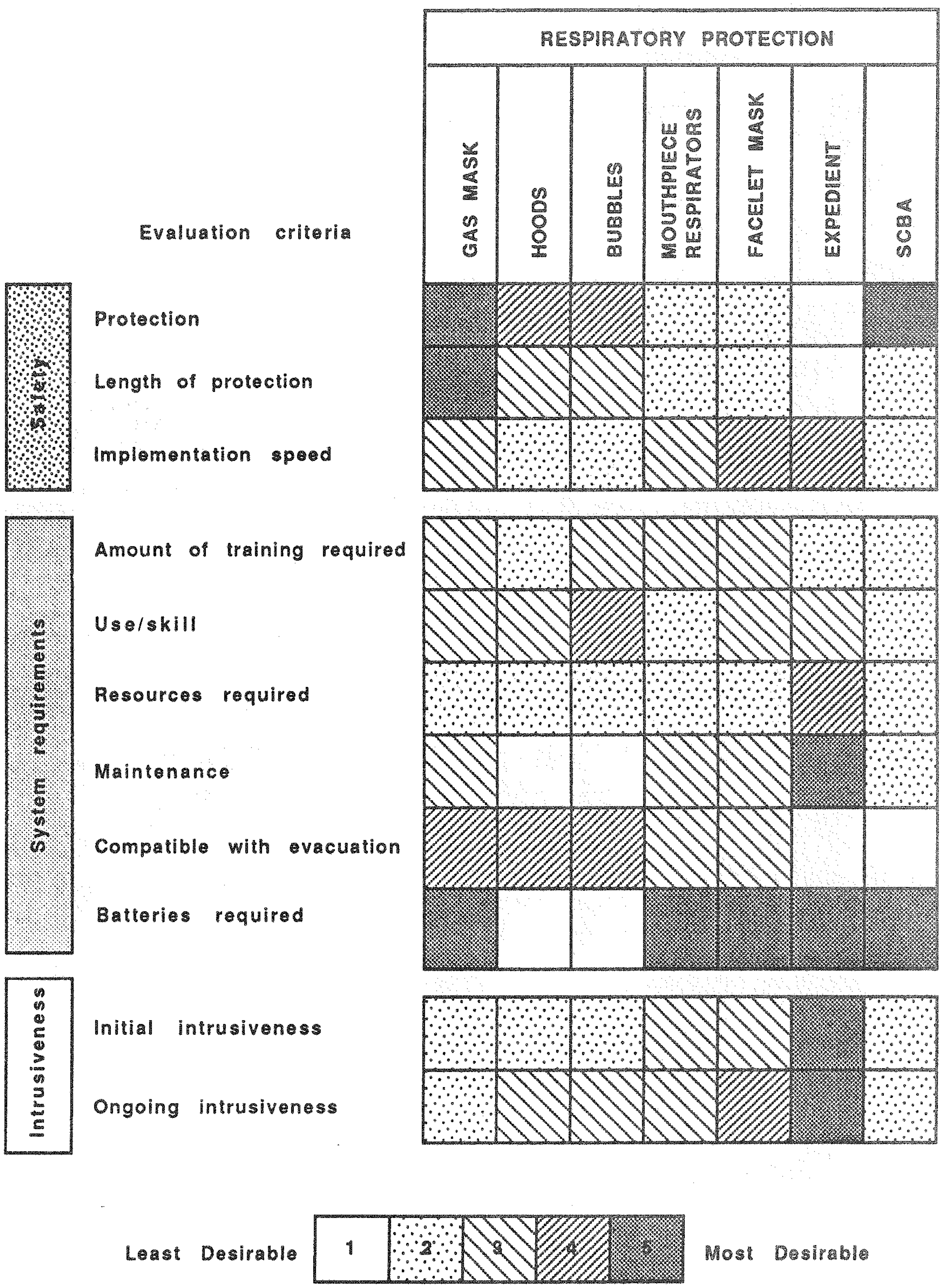

Fig. 5.2. Expert panel evaluation of respiratory protection options.

Table 5.1 Potential protective actions in the IRZ for TEAD

Option	Adults	Children	Infants	Institutions	Impaired
Evacuate	No	No	No	No	No
Normal shelter	No	No	No	No	No
Specialized shelter	Yes	Yes	Yes	No	No
Expedient shelter	Yes	Yes	Yes	No	No
Pressurized room	Yes	Yes	Yes	Yes	Yes
Pressurized building	Yes	Yes	Yes	Yes	Yes
Enhanced shelter	Yes	Yes	Yes	Yes	Yes
Gas mask	Yes	No	No	No	No
Hoods	NA	Yes	No	NA	NA
Bubbles	NA	No	Yes	NA	NA
Mouthpiece respirator	No	No	No	No	No
Facelet mask	No	No	No	No	No
Expedient respirator	No	No	No	No	No
SCBA	No	No	No	Yes	No
Special protective clothing	Yes	Yes	Yes	No	No
Expedient protective clothing[1]	No	No	No	No	No
Prophylactic drug	No	No	No	No	No
Antidotes[2]	No	No	No	Yes	No
Evacuate/respir. prot.	Yes	Yes	Yes	No	No
Respir. prot./shelter	Yes	Yes	Yes	No	No

NA = Not applicable

[1] If the potential for exposure to mustard or VX agent exists, the use of expedient protective clothing should be considered.

[2] If exposure to mustard or VX agent aerosol is suspected, decontamination procedures should be implemented as described above.

recommendations in the future or provide more detailed information that distinguishes among the relative effectiveness of each option. Furthermore, the differentiation of actions for the PAZ and IRZ are not magical, although in the case of TEAD the physical barriers help solidify the distinctions. In addition, it should be stressed that a combination of protective action options may be needed to protect the public from a range of accident scenarios.

5.4.1 IRZ Options

Viable protective action options involving sheltering for the general population including adults, children, and infants in the IRZ include expedient sheltering, enhanced shelter, pressurizing a room or building, and mass

Table 5.2 Potential protective actions in the PAZ for TEAD

Option	Adults	Children	Infants	Institutions	Impaired
Evacuate	Yes	Yes	Yes	Yes	Yes
Normal shelter	No	No	No	No	No
Specialized shelter	Yes	Yes	Yes	Yes	Yes
Expedient shelter	Yes	Yes	Yes	No	No
Pressurized room	Yes	Yes	Yes	Yes	Yes
Pressurized building	No	No	No	Yes	No
Enhanced shelter	Yes	Yes	Yes	Yes	Yes
Gas mask	No	No	No	No	No
Hoods	NA	No	No	NA	NA
Bubbles	NA	No	No	NA	NA
Mouthpiece respirator	No	No	No	No	No
Facelet mask	No	No	No	No	No
Expedient respiratory prot.	No	No	No	No	No
SCBA	No	No	No	No	No
Special protective clothing	No	No	No	No	No
Expedient protective clothing	No	No	No	No	No
Prophylactic drug	No	No	No	No	No
Antidotes[1]	No	No	No	No	No
Evacuate/respir. prot.	Yes	Yes	Yes	No	No
Respir. prot./shelter	No	No	No	No	No

NA = Not applicable

[1] If exposure to mustard or VX agent aerosol is suspected, decontamination procedures should be implemented as described above.

shelter. Normal sheltering is not recommended for anyone because it afford less protection than the other sheltering options.

The only viable respiratory option for adults is a face mask. Masks are not recommended for children or infants due to difficulties in achieving a tight fit. Expedient respiratory protection is not recommended for anyone because it offers little protection against toxic vapors. Facelet masks do not offer protection for a sufficient time nor a very high level of protection. SCBA and mouthpiece respirators offer protection for an insufficient time. For infants, bubbles are a potential option, as are hoods for children. These are not designed for use by adults. Furthermore, bubbles are not recommended for children because of the likely difficulties in use. Hoods are not recommended for infants for the same reason.

For institutions (at this time no institutions exists within the IRZ for TEAD) and impaired populations pressurization of a room or building is recommended. The exact choice depends on the nature of the institution or impairment. Expedient sheltering is not recommended due to implementation difficulties. For certain institutions such as health care facilities, some form of SCBA may be feasible. All other forms of respiratory protection would be very difficult to implement.

Evacuation, *per se*, is not recommended for any population subgroup in the IRZ. A feasible option at TEAD is to don respiratory protection such as face mask, facelet mask, or a mouthpiece respirator (or appropriate hood or bubblefor children or infant) and then evacuate. This is not feasible for institutions or for the impaired to implement.

The combination of an appropriate respiratory protective device (mask, hood, or bubble) with some form of enhanced or expedient sheltering is an option for the general public but not for institutions or for the impaired.

Antidotes and prophylactics for nerve agents are not recommended for distribution to the general population because their administration requires trained medical workers. This could be an option at institutions with staff who can be trained to use such drugs. Although there are no antidotes for mustard exposure, prompt decontamination and symptomatic therapy after suspicion of exposure to a mustard release are advised. Use of household products (e.g., tissue paper, flour, talcum powder, washing abrasive, and salad oil) may be effective in removing mustard from the skin. Copious flushing with water is recommended for eye contamination.

5.4.2 PAZ Options

The PAZ options differ from the IRZ options at TEAD for several reasons. First, a much greater amount of time will be available to implement actions. Second, agent concentrations are expected to be much lower because significant dilution and dispersion will have occurred. Third, the population is more densely arranged in some locations of the PAZ than in the IRZ.

Normal evacuation is an option for all populations in the PAZ as is pressurization of a room or a mass shelter. Pressurization of a building is not needed because sufficient time would exist to move people to a part of a building, or to a mass shelter, although this option should be retained for institutions. Other forms of sheltering are options as well. Respiratory protection and normal sheltering are not recommended because evacuation and expedient sheltering are always preferred options. The use of respiratory protection during evacuation is a possible option. The use of drugs are not recommended for any group because the time and means exist to avoid exposure entirely. Even though the possibility of skin exposure is extremely limited for persons implementing the above protective actions in the PAZ, it is still advisable to implement decontamination procedures, particularly since they require only very limited resources and have no adverse side effects.

5.4.3 Beyond the PAZ

In areas beyond the PAZ the two options are evacuation or normal sheltering. The latter would be used solely as a precautionary mechanism because all areas with a potential for exposure would be evacuated.

5.4.4 Conclusions

In this section preliminary conclusions are presented regarding protective action options at TEAD based on the information presented on accident distribution (see Sect. 2 and Appendix A), topography, meteorology, and population (see Sect. 3). It must be stressed that these conclusions are preliminary. They are offered mainly to stimulate discussion and debate on the protective action issue. They may change based on new information from the technical support studies or elsewhere.

First, for the general population in the IRZ, the recommended option is to evacuate with respiratory protection. This is recommended for three reasons: (1) there is a buffer of land between the potential accident sites and the population that should allow sufficient time for safe mobilization (the respiratory protection allows added safety); (2) there are clear evacuation routes away from the installation; and (3) the low population density removes the constraints of possible traffic bottlenecks. At this point the recommended form of respiratory protection for the adult unimpaired population is a mouthpiece respirator with a snorkel-type mouthpiece and strap for hanging it around the neck. This equipment was designed for use in industrial accidents for workers evacuating out of a toxic environment. Recommended respiratory protection for infants and children are baby bubbles and hoods, respectively.

A second recommended option is expedient sheltering (see Sect. 5.1). For most accident scenarios expedient sheltering is less desirable than evacuation. Given an instantaneous release, expedient shelter may afford a higher degree of protection. Precise criteria establishing when such conditions would exist have not been developed. Protective clothing and decontamination are both recommended as means of minimizing the possibility of adverse effects of mustard or VX agent deposition on the skin.

Other options that are potentially feasible for protecting the general population in the IRZ include sealing a house, pressurizing one room or a building, using respirators while sheltering, or mass pressurized shelter. Antidotes for the general population are not recommended.

For any persons that are impaired such that evacuation is not feasible, positive pressurization of a "safe" room in the house or the entire building depending on the exact circumstances is recommended. Impairments that would prevent evacuation would also preclude expedient sheltering.

For the PAZ evacuation is recommended for all population groups. Sufficient time exists that with pre-planning all people can be evacuated. This requires the identification of evacuation resources to move people without transportation and institutional populations.

6.0 PROGRAM CONSIDERATIONS

In this section some additional information is presented regarding how the program guidance can be implemented for the TEAD chemical stockpile based on the information previously presented on accident distribution, meteorology, topography, population characteristics, and protective action recommendations. Without the adoption and implementation of appropriate standards for command and control decisions and for alert and notification systems, the effectiveness of the recommended protective actions is greatly diminished.

6.1 STANDARDS

Given the accidents that could occur at the TEAD-S facility, an overall command and control structure must be able to provide a decision on warning and protective actions in less than ten (10) minutes. This will enable the nearest populations to take a protective action. To meet this objective, the development of a rapid accident classification and decision support system is needed.

Because of the short or nonexistent lead times and the remoteness of the TEAD-S area, it would be extremely important to delegate authority to the Army to make a protective action recommendation and activate the alert/notification system in the IRZ. Although a quick decision to implement protective actions in the PAZ is also desirable, it is possible to work out a procedure for a rapid civilian decision process. This capability must exist on a 24-hour basis. Sufficient flexibility and redundancy in the procedure should be provided to allow a fairly rapid decision for protective actions in the PAZ (e.g., within 30 minutes at the maximum).

Rapid notification of the public is needed in the IRZ. Because of the rural nature of the area, it is necessary to have outdoor and indoor alert and notification mechanisms. Electronic sirens with loudspeaker capabilities are recommended for outdoors and either tone alert radio or telephone switching systems are recommended.

With a longer available warning time for the PAZ, a combination of a siren system along with emergency broadcast system (EBS) for densely populated areas and route alert along with EBS for sparsely populated areas are recommended.

6.2 IMPLEMENTATION

Ultimately the nature of the emergency planning program at TEAD must be established by local decision makers. The general schedule for the program has been presented in the *Management Plan for Emergency Response Activities* (Baldwin, et al. forthcoming). Detailed planning questions are provided in Appendix E. In order to establish an enhanced readiness capability at the local level, the logical steps to follow are as follows:

(1) Finalize EPZ boundaries. Recommendations have been made about potential IRZ and PAZ boundaries in this report. The methodology used to arrive at these recommendations has also been specified (see Sect. 4). It is important that community decision makers work through the options and come to agreement about the geographic definition of the IRZ and PAZ as the first step of the planning process. As noted previously, the final determination of EPZ boundaries will be made collectively by affected local governments, state government, the Department of the Army, and the Federal Emergency Management Agency.

(2) Decide on interim (based on current capabilities) and final protective action strategies for each population group in the IRZ and PAZ. Potential and recommended protection actions and their advantages and disadvantages have been identified in Sect. 5 of this report.

(3) Agree to new warning system, communications systems, and command and control system designs. Such systems are critical to an effective emergency response capability. They also represent a major capital investment in equipment. The systems will likely be installed in a phased manner with critical and basic equipment that will not be obsolete to the entire system being installed on a rapid track. It is important that communities help design and ultimately approve the new systems.

(4) Begin public education/awareness activities. People need to know what to do in an accident situation. This information cannot be withheld until a formal public education program is adopted and implemented. There is a need for a preliminary information effort until the formal public affairs/ education program is established.

(5) Estimate resources needed to implement protective action strategies. This includes the following major items as well as other resources identified in the *Program Guidance* document (Schneider Engineering 1989):

- protective equipment for workers and the public,
- emergency worker requirements,
- mass shelter and decontamination needs,
- transportation and traffic control,
- emergency operations center (EOC), and
- monitoring equipment.

(6) Install new warning, command/control, and communications systems.

(7) Install protective action equipment (if needed). Depending on the protective action strategy adopted, it may be necessary to install or distribute equipment to the public and provide the appropriate training.

(8) Develop final plans and implementation procedures. The installation of new systems will require modification of the Phase I planning upgrades (see Sect. 1). The details associated with these steps are specified in the *Program Guidance* document.

6.3 CONCLUSIONS

This report has identified the basic features of the emergency response planning process associated with the unitary chemical stockpile and its disposal at TEAD-S. It has identified information needed to make basic decisions (e.g., EPZ determination, protection action selection) and provided some of that information - what kinds of accidents could occur with what kinds of lethal downwind distances assuming different meteorological conditions and the actual distribution of meteorological, topographic, and population resources in the TEAD-S area. It has further provided methodologies for determining the emergency planning zone and sub-zones and evaluating potential protective actions.

The next phase of the planning process must involve local decision makers. They need to digest this and other information (e.g., *Management Plan for Emergency Response Activities* and the *Program Guidance* document) and make decisions such as those enumerated above. They need to consider additional information as it becomes available (e.g., technical support studies) and determine whether and how that information affects their earlier decisions. In short, as noted in Sect. 1, they need to create their own plan. The Army and other participating organizations are ready and available to provide assistance to local decision makers in furthering the objective of emergency preparedness, but only they can make it work.

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APPENDIX A

DISTRIBUTION OF ACCIDENTAL RELEASES FOR TEAD

APPENDIX A

DISTRIBUTION OF ACCIDENTAL RELEASES FOR TEAD

This appendix characterizes all accidental releases that have been identified in the CSDP risk analyses that could occur at TEAD (MITRE Corporation 1987). Table A.1 presents information for each accident scenario that might occur during disposal activities. Table A.2 consists of a brief verbal description of each accident scenario listed in Table A.1. Tables A.3 and A.4 present corresponding information for accidents that could occur during storage and associated handling activities.

In Tables A.1 and A.3, the potential releases associated with disposal and storage/handling accidents, respectively, are arranged to display the range of values for those variables that are particularly important for emergency planning. The first column identifies the activity during which the particular accident occurs and the scenario number assigned to that accident (this column can be used to find the verbal description of the accident scenario in Table A.2 or A.4).

The second and third columns present the maximum downwind distances at which fatalities to healthy adults might occur under most likely and very stable meteorological conditions, respectively. These values were calculated using the Army's D2PC atmospheric dispersion code (Whitacre, *et al.* 1986). The most likely meteorological conditions are defined as neutral atmospheric stability (D stability) and moderate wind speeds (3 m/s). The very stable meteorological conditions are defined as high atmospheric stability (E stability) and low winds (1 m/s).

Columns four through eight list the mass of agent (in pounds) that would be releases by each accident. Column four presents the estimated total amount of agent that would be released. Columns five through seven break this total down into the amounts that would be detonated, emitted (immediately vaporized), and evaporated, respectively. Column eight lists the amount of agent that would be spilled but, because of accident containment activities, would not contribute to the atmospheric release.

The event duration (column nine) represents the length of time (in minutes) during which the release could occur. When the value in this column is zero, all the agent would be released instantaneously, as with a detonation with no resultant fire. Longer values (e.g., 20 min through 360 min) represent the estimated length of time that the release would continue before the available agent was depleted or the accident was contained.

Columns 10 and 11 present the type of munition and agent, respectively, involved in the accidental release. The type of munition influences the nature of the release (e.g., through detonation) as well as the actions the on-site personnel should take to contain the accident. The type of agent, because of different agent characteristics (e.g., volatility and toxicity), is important in estimating the fatal plume distances and determining appropriate protective actions.

The final column, Release Mode, designates whether the agent is released as a simple vapor (spill), is propelled by a fire, or is released in a complex manner involving a combination of spill, fire, and detonation. These release modes correspond to a different nomenclature used in the atmospheric dispersion modeling: a spill is equivalent to an evaporative release; a fire is equivalent to a semi-continuous release; and a detonation, which occurs in the risk analysis database only as a component of a complex release, is equivalent to an instantaneous release. Under both nomenclatures, a complex release is considered to consist of some combination of these simple release modes.

Table A.1 Accident scenarios for on-site disposal activities at TEAD
(sorted by munition type, agent within munition type, and activity within munition type)

Activity ID[1] and scenario	ML[2] plume distance (Km)	VS[3] plume distance (Km)	Amount of agent released: Total (lb)	Detonated (lb)	Emitted (lb)	Evaporated (lb)	Amount of agent unreleased (lb)	Event duration (min)	Munition type[4]	Agent type[5]	Release mode[6]
PO 21	1.40	4.90	110.154	0.000	0.000	110.154	548.277	60	A	G	S
PO 22	1.24	4.45	54.828	0.000	54.828	0.000	0.000	10	A	G	F
PO 41	1.68	6.27	101.391	0.000	101.391	0.000	0.000	15	A	G	C
PO 22	0.24	0.83	31.915	0.000	31.915	0.000	0.000	10	A	H	F
PO 22	0.92	3.13	12.706	0.000	12.706	0.000	0.000	10	A	V	F
HO 1	0.33	1.05	4.256	0.000	4.256	0.000	0.000	15	B	G	C
HO 3	0.33	1.05	4.256	0.000	4.256	0.000	0.000	15	B	G	C
HO 4	0.33	1.05	4.256	0.000	4.256	0.000	0.000	15	B	G	C
HO 5	0.57	1.62	12.106	0.000	0.000	12.106	219.786	15	B	G	S
HO 6	0.78	2.67	21.979	0.000	21.979	0.000	0.000	10	B	G	F
HO 7	0.57	1.62	12.106	0.000	0.000	12.106	219.786	15	B	G	S
VO 1	0.21	0.55	1.879	0.000	0.000	1.879	219.786	15	B	G	S
VO 3	0.21	0.55	1.879	0.000	0.000	1.879	219.786	15	B	G	S
VO 9	0.21	0.55	1.879	0.000	0.000	1.879	219.786	15	B	G	S
HF 1	0.57	1.62	12.106	0.000	0.000	12.106	219.786	15	B	G	S
HF 7	0.57	1.62	12.106	0.000	0.000	12.106	219.786	15	B	G	S
PO 25	0.46	1.68	21.979	0.000	21.979	0.000	0.000	360	B	G	C
PO 29	1.67	7.84	264.241	0.000	264.241	0.000	0.000	360	B	G	C
PO 42	0.78	2.67	21.979	0.000	21.979	0.000	0.000	12	B	G	C
HO 11	0.33	1.01	1.758	1.600	0.160	0.000	0.000	60	C	G	C
HO 12	0.33	1.01	1.758	1.600	0.160	0.000	0.000	60	C	G	C
VO 4	1.85	6.35	49.888	38.371	11.508	0.000	0.000	20	C	G	C

Table A.1 Accident scenarios for on-site disposal activities at TEAD (continued)

Activity ID[1] and scenario	ML[2] plume distance (Km)	VS[3] plume distance (Km)	Amount of agent released: Total (lb)	Amount of agent released: Detonated (lb)	Amount of agent released: Emitted (lb)	Amount of agent released: Evaporated (lb)	Amount of agent unreleased (lb)	Event duration (min)	Munition type[4]	Agent type[5]	Release mode[6]
HF 11	0.51	1.46	4.055	1.600	0.000	2.455	7.998	60	C	G	C
HF 12	0.32	0.96	1.600	1.600	0.000	0.000	0.000	0	C	G	C
HF 13	0.33	1.01	1.758	1.600	0.160	0.000	0.000	60	C	G	C
PO 29	2.26	7.95	74.817	57.544	17.298	0.000	0.000	360	C	G	C
PO 33	2.26	7.95	74.817	57.544	17.298	0.000	0.000	360	C	G	C
PO 42	0.39	1.25	5.794	0.000	5.794	0.000	0.000	12	C	G	C
PO 49	0.32	0.96	1.600	1.600	0.000	0.000	0.000	0	C	G	C
PO 50	0.32	0.96	1.600	1.600	0.000	0.000	0.000	0	C	G	C
PO 52	0.32	0.96	1.600	1.600	0.000	0.000	0.000	0	C	G	C
VO 4	0.83	3.37	331.131	287.740	43.152	0.000	0.000	20	D	H	C
PO 29	1.03	4.30	496.592	431.519	64.863	0.000	0.000	360	D	H	C
PO 33	1.03	4.30	496.592	431.519	64.863	0.000	0.000	360	D	H	C
HO 1	0.41	1.32	6.397	0.000	6.397	0.000	0.000	15	K	G	C
HO 4	0.41	1.32	6.397	0.000	6.397	0.000	0.000	15	K	G	C
HO 5	1.38	4.29	68.077	0.000	0.000	68.077	1499.680	15	K	G	S
HO 6	2.04	7.78	149.968	0.000	149.968	0.000	0.000	10	K	G	F
HO 7	1.38	4.29	68.077	0.000	0.000	68.077	1499.680	15	K	G	S
VO 1	0.53	1.50	10.568	0.000	0.000	10.568	1499.680	15	K	G	S
VO 3	0.53	1.50	10.568	0.000	0.000	10.568	1499.680	15	K	G	S
VO 9	0.53	1.50	10.568	0.000	0.000	10.568	1499.680	15	K	G	S
HF 1	1.38	4.29	68.077	0.000	0.000	68.077	1499.680	15	K	G	S
HF 3	2.04	7.78	149.968	0.000	149.968	0.000	0.000	10	K	G	F

Table A.1 Accident scenarios for on-site disposal activities at TEAD (continued)

Activity ID[1] and scenario	ML[2] plume distance (Km)	VS[3] plume distance (Km)	Amount of agent released: Total (lb)	Detonated (lb)	Emitted (lb)	Evaporated (lb)	Amount of agent unreleased (lb)	Event duration (min)	Munition type[4]	Agent type[5]	Release mode[6]
HF 7	1.38	4.29	68.077	0.000	0.000	68.077	1499.680	15	K	G	S
PO 25	1.25	5.53	149.968	0.000	149.968	0.000	0.000	360	K	G	C
PO 26	3.11	16.52	899.498	0.000	899.498	0.000	0.000	360	K	G	C
PO 29	3.11	16.52	899.498	0.000	899.498	0.000	0.000	360	K	G	C
PO 42	1.02	3.60	37.497	0.000	37.497	0.000	0.000	12	K	G	C
PO 45	0.93	3.65	50.350	0.000	50.350	0.000	0.000	106	K	G	F
PO 51	0.69	2.62	28.973	0.000	28.973	0.000	0.000	61	K	G	F
HO 2	0.41	1.50	84.918	0.000	84.918	0.000	0.000	10	K	H	F
HO 6	0.41	1.50	84.918	0.000	84.918	0.000	0.000	10	K	H	F
HF 3	0.41	1.50	84.918	0.000	84.918	0.000	0.000	10	K	H	F
PO 25	0.41	1.50	84.918	0.000	84.918	0.000	0.000	360	K	H	C
PO 26	1.04	4.37	510.505	0.000	510.505	0.000	0.000	360	K	H	C
PO 29	1.04	4.37	510.505	0.000	510.505	0.000	0.000	360	K	H	C
PO 42	0.28	0.99	42.462	0.000	42.462	0.000	0.000	12	K	H	C
PO 51	0.18	0.59	17.989	0.000	17.989	0.000	0.000	69	K	H	F
HO 6	1.64	6.06	39.994	0.000	39.994	0.000	0.000	10	K	V	F
PO 25	1.00	4.16	39.994	0.000	39.994	0.000	0.000	360	K	V	C
PO 29	2.50	12.91	239.883	0.000	239.883	0.000	0.000	360	K	V	C
PO 42	1.64	6.06	39.994	0.000	39.994	0.000	0.000	12	K	V	C
HO 11	1.64	5.39	31.477	31.477	0.000	0.000	0.000	60	M	V	C
VO 4	7.52	32.87	827.942	377.572	449.780	0.590	0.000	20	M	V	C
HF 11	1.64	5.39	31.477	31.477	0.000	0.000	157.398	60	M	V	C
HF 12	0.96	2.91	10.495	10.495	0.000	0.000	0.000	0	M	V	C
PO 29	6.55	27.89	609.537	567.545	42.560	0.000	0.000	360	M	V	C

Table A.1 Accident scenarios for on-site disposal activities at TEAD (continued)

Activity ID[1] and scenario	ML[2] plume distance (Km)	VS[3] plume distance (Km)	Amount of agent released				Amount of agent unreleased (lb)	Event duration (min)	Munition type[4]	Agent type[5]	Release mode[6]
			Total (lb)	Detonated (lb)	Emitted (lb)	Evaporated (lb)					
PO 33	6.55	27.89	609.537	567.545	42.560	0.000	0.000	360	M	V	C
PO 52	0.96	2.91	10.495	10.495	0.000	0.000	0.000	0	M	V	C
HO 11	0.66	2.07	6.607	6.501	0.110	0.000	0.000	60	P	G	C
HO 12	0.66	2.07	6.607	6.501	0.110	0.000	0.000	60	P	G	C
VO 4	4.45	17.31	307.610	52.000	255.270	0.339	0.000	20	P	G	C
HF 11	1.02	3.02	15.171	6.501	0.000	8.670	32.509	60	P	G	C
HF 12	0.66	2.06	6.501	6.501	0.000	0.000	0.000	0	P	G	C
PO 29	2.62	9.40	101.391	77.983	23.388	0.000	0.000	360	P	G	C
PO 33	2.62	9.40	101.391	77.983	23.388	0.000	0.000	360	P	G	C
PO 42	0.65	2.20	15.596	0.000	15.596	0.000	0.000	12	P	G	C
PO 49	0.66	2.06	6.501	6.501	0.000	0.000	0.000	0	P	G	C
PO 50	0.66	2.06	6.501	6.501	0.000	0.000	0.000	0	P	G	C
VO 4	0.66	2.60	213.304	93.541	119.950	0.000	0.000	20	P	H	C
PO 29	0.57	2.20	161.436	140.281	21.038	0.000	0.000	360	P	H	C
PO 33	0.57	2.20	161.436	140.281	21.038	0.000	0.000	360	P	H	C
HO 11	0.72	2.14	5.998	5.998	0.000	0.000	0.000	60	P	V	C
HO 12	0.72	2.14	5.998	5.998	0.000	0.000	0.000	60	P	V	C
VO 4	2.50	8.85	76.384	47.973	28.379	0.000	0.000	20	P	V	C
HF 11	0.72	2.14	5.998	5.998	0.000	0.000	29.992	60	P	V	C
HF 12	0.72	2.14	5.998	5.998	0.000	0.000	0.000	0	P	V	C
PO 29	2.52	8.92	77.268	71.945	5.395	0.000	0.000	360	P	V	C
PO 33	2.52	8.92	77.268	71.945	5.395	0.000	0.000	360	P	V	C
PO 49	0.72	2.14	5.998	5.998	0.000	0.000	0.000	0	P	V	C
PO 50	0.72	2.14	5.998	5.998	0.000	0.000	0.000	0	P	V	C

Table A.1 Accident scenarios for on-site disposal activities at TEAD (continued)

Activity ID[1] and scenario	ML[2] plume distance (Km)	VS[3] plume distance (Km)	Amount of agent released: Total (lb)	Detonated (lb)	Emitted (lb)	Evaporated (lb)	Amount of agent unreleased (lb)	Event duration (min)	Munition type[4]	Agent type[5]	Release mode[6]
HF 11	1.49	4.60	32.285	14.488	0.000	17.797	72.444	60	Q	G	C
HF 12	0.99	3.20	14.488	14.488	0.000	0.000	0.000	0	Q	G	C
PO 29	3.36	12.50	169.824	130.617	39.174	0.000	0.000	360	Q	G	C
PO 33	3.36	12.50	169.824	130.617	39.174	0.000	0.000	360	Q	G	C
PO 49	0.99	3.20	14.488	14.488	0.000	0.000	0.000	0	Q	G	C
HF 12	1.12	3.49	14.488	14.488	0.000	0.000	0.000	0	Q	V	C
HO 11	1.24	4.07	22.439	21.380	1.040	0.000	0.000	60	R	G	C
VO 4	3.30	12.26	164.059	160.325	3.597	0.000	0.000	20	R	G	C
VO 12	3.70	14.00	208.449	160.325	48.195	0.000	0.000	20	R	G	C
HF 11	1.91	6.04	53.456	21.380	0.000	32.076	138.995	60	R	G	C
HF 12	0.85	2.70	10.691	10.691	0.000	0.000	0.000	0	R	G	C
PO 29	4.49	17.49	313.329	240.991	72.277	0.000	0.000	360	R	G	C
PO 33	4.49	17.49	313.329	240.991	72.277	0.000	0.000	360	G	G	C
PO 49	0.85	2.70	10.691	10.691	0.000	0.000	0.000	0	R	G	C
PO 50	0.85	2.70	10.691	10.691	0.000	0.000	0.000	0	R	G	C
PO 52	0.85	2.70	10.691	10.691	0.000	0.000	0.000	0	R	G	C
HO 11	1.32	4.18	19.999	19.999	0.000	0.000	0.000	60	R	V	C
VO 4	3.70	14.11	176.198	149.968	26.122	0.000	0.000	20	R	V	C
VO 12	3.55	13.43	161.065	149.968	11.246	0.000	0.000	20	R	V	C
HF 11	1.32	4.18	19.999	19.999	0.000	0.000	130.017	60	R	V	C
HF 12	0.94	2.84	10.000	10.000	0.000	0.000	0.000	0	R	V	C
PO 29	4.28	16.81	241.546	224.905	16.866	0.000	0.000	360	R	V	C
PO 33	4.28	16.81	241.546	224.905	16.866	0.000	0.000	360	R	V	C
PO 49	0.94	2.84	10.000	10.000	0.000	0.000	0.000	0	R	V	C

Table A.1 Accident scenarios for on-site disposal activities at TEAD (continued)

Activity ID[1] and scenario	ML[2] plume distance (Km)	VS[3] plume distance (Km)	Amount of agent released: Total (lb)	Detonated (lb)	Emitted (lb)	Evaporated (lb)	Amount of agent unreleased (lb)	Event duration (min)	Munition type[4]	Agent type[5]	Release mode[6]
PO 50	0.94	2.84	10.000	10.000	0.000	0.000	0.000	0	R	V	C
PO 52	0.94	2.84	10.000	10.000	0.000	0.000	0.000	0	R	V	C
HO 6	1.51	5.51	33.884	0.000	33.884	0.000	0.000	10	S	V	F
HF 3	1.51	5.51	33.884	0.000	33.884	0.000	0.000	10	S	V	F
PO 25	0.92	3.75	33.963	0.000	33.963	0.000	0.000	360	S	V	C
PO 26	2.29	11.64	203.236	0.000	203.236	0.000	0.000	360	S	V	C
PO 29	2.29	11.64	203.236	0.000	203.236	0.000	0.000	360	S	V	C
PO 42	1.51	5.51	33.884	0.000	33.884	0.000	0.000	12	S	V	C
VO 1	0.27	0.70	2.844	0.000	0.000	2.844	348.337	15	W	G	S
VO 3	0.27	0.70	2.844	0.000	0.000	2.844	348.337	15	W	G	S
VO 9	0.27	0.70	2.844	0.000	0.000	2.844	348.337	15	W	G	S

[1] Activity ID (activity during which accident occurs)
HF = Handling at the disposal facility
HO = On-site handling away from the disposal facility
PO = Plant operations
VO = On-site transportation associated with on-site disposal

[2] MS = most likely meteorological condition of 3 m/s wind speed and D stability.

[3] VS = very stable meteorological condition of 1 m/s wind speed and E stability.

Table A.1 Accident scenarios for on-site disposal activities at TEAD (continued)

[4] Munition Type

A = All munitions
B = Bombs
C = Cartridges (105mm)
D = Mortar shells (4.2 in.)
K = Bulk ("ton") containers
M = Mines
P = Projectiles (155mm)
Q = Projectiles (8 in.)
R = Rockets
S = Spray tanks
W = Wet-eye bombs

[5] Agent Type

G = Agent GB ("Sarin")
H = Agents H, HT, HD ("Mustard")
V = Agent VX

[6] Release Mode

C = Complex mode (including combinations of simple modes and indoor releases affected by building systems)
F = Fire (incomplete combustion)
S = Spill (leading to partial evaporation)

Table A.2 Scenario descriptions for accidents during on-site disposal activities at TEAD

Activity code & scenario ID	Scenario description
HF 001	Munition pallet or container dropped during movement from munitions handling igloo (MHI) to munitions demilitarization building (MDB).
HF 003	Forklift collision accident with short duration fire during handling between MHI and MDB.
HF 007	Collision accident without fire.
HF 011	Drop of munition pallet between the MHI and MDB leads to detonation.
HF 012	Drop of bare single munition inside the MDB leads to detonation.
HF 013	Drop of palletized munition (in container) inside the MDB leads to detonation.
HO 001	Drop of bare pallet or single item at storage area.
HO 002	Forklift collision with short duration fire at storage area involving bare munitions.
HO 003	Forklift tine accident involving bare munitions at storage area.
HO 004	Forklift collision accident without fire at storage area involving bare munitions.
HO 005	Drop of on-site transport container.
HO 006	Forklift collision with short duration fire during handling of on-site transport container.
HO 007	Forklift collision without fire during handling of on-site transport container.
HO 011	Drop of bare palletized munition leads to detonation.
HO 012	Forklift collision accident at storage area leads to detonation of burstered munition.
PO 021	Direct crash of a large or small aircraft damages the outdoor agent piping system at TEAD, no fire.
PO 022	Direct crash of a large or small aircraft damages the outdoor agent piping system at TEAD, fire occurs and not contained.

Table A.2 Scenario descriptions for accidents during on-site disposal activities at TEAD (continued)

Activity code & scenario ID	Scenario description
PO 025	Earthquake damages the MDB structure, munitions fall and are punctured, fire suppressed.
PO 026	Earthquake damages the MDB structure, munitions fall and are punctured, earthquake also initiates fire, fire suppression system fails.
PO 029	Earthquake damages the MDB; munitions are intact; fire occurs; fire suppression system fails.
PO 033	Earthquake causes munitions to fall but no detonation occurs, the MDB is intact, the toxic cubicle (TOX) is intact; earthquake also initiates fire, fire suppression system fails.
PO 041	Failure to stop agent feed to the liquid incinerator (LIC), overloads the ventilation system.
PO 042	Metal parts furnace (MPF) explosion due to failure to stop fuel flow after a shutdown.
PO 045	Ton container is spilled in the explosive containment vestibule (ECV), MDB structure fails due to subsequent agent fire.
PO 049	Munition detonation in explosive containment room (ECR) causes structural and ventilation system failure.
PO 050	Munition detonation in ECR causes structural failure, a fire, and ventilation failure.
PO 051	Ton container spill in the munitions processing bay (MPB) results in fire and structural failure.
PO 052	A burstered munition is fed to the dunnage incinerator (DUN).
VO 001	A munitions vehicle collision/overturn occurs and crush forces fail the agent containment.
VO 003	A munitions vehicle collision/overturn occurs and puncture forces fail the agent containment.

Table A.2 Scenario descriptions for accidents during on-site disposal activities at TEAD (continued)

Activity code & scenario ID	Scenario description
VO 004	A munitions vehicle accident with fire occurs, causing detonation of werbursted munitions. Ignition of the propellant by a probe could also detonate the burster of a cartridge, and the burster of a rocket could be detonated by impact-induced ignition of the rocket propellant.
VO 009	A severe earthquake occurs, causing a munitions vehicle accident and crush forces fail the agent containment.
VO 012	A severe earthquake occurs, causing a munitions vehicle accident, and fire fails and detonates burstered munitions.

Table A.3 Accident scenarios for storage and handling activities at TEAD
(sorted by munition type, agent within munition type, and activity within munition type)

Activity ID[1] and scenario	ML[2] plume distance (Km)	VS[3] plume distance (Km)	Amount of Agent Released: Total (lb)	Detonated (lb)	Emitted (lb)	Evaporated (lb)	Amount of agent unreleased (lb)	Event duration (min)	Munition type[4]	Agent type[5]	Release mode[6]
HS 1	0.33	1.05	4.256	0.000	4.256	0.000	0.000	15	B	G	C
HS 3	0.33	1.05	4.256	0.000	4.256	0.000	0.000	15	B	G	C
HS 4	0.33	1.05	4.256	0.000	4.256	0.000	0.000	15	B	G	C
HS 8	0.33	1.05	4.256	0.000	4.256	0.000	0.000	15	B	G	C
HS 9	0.33	1.05	4.256	0.000	4.256	0.000	0.000	15	B	G	C
HS 10	0.33	1.05	4.256	0.000	4.256	0.000	0.000	15	B	G	C
SL 2	0.25	0.83	4.256	0.000	4.256	0.000	0.000	60	B	G	C
SL 7	0.50	1.84	25.586	0.000	25.586	0.000	0.000	360	B	G	C
SL 9	0.25	0.83	4.256	0.000	4.256	0.000	0.000	60	B	G	C
HS 5	0.37	1.12	2.143	1.600	0.545	0.000	0.000	60	C	G	C
HS 6	0.37	1.12	2.143	1.600	0.545	0.000	0.000	60	C	G	C
HS 7	0.92	2.94	12.474	9.594	2.877	0.000	0.000	20	C	G	C
HS 11	0.37	1.12	2.143	1.600	0.545	0.000	0.000	60	C	G	C
SL 22	0.37	1.12	2.143	1.600	0.545	0.000	0.000	360	C	G	C
SL 25	0.37	1.12	2.143	1.600	0.545	0.000	0.000	120	C	G	C
HS 1	0.41	1.32	6.397	0.000	6.397	0.000	0.000	15	K	G	C
HS 2	2.04	7.78	149.968	0.000	149.968	0.000	0.000	30	K	G	F
HS 4	0.41	1.32	6.397	0.000	6.397	0.000	0.000	15	K	G	C
SL 7	0.60	2.32	37.068	0.000	37.068	0.000	0.000	360	K	G	C
SL 9	0.31	1.06	6.397	0.000	6.397	0.000	0.000	60	K	G	C
HS 2	0.41	1.50	84.918	0.000	84.918	0.000	0.000	30	K	H	F
SL 8	11.91	85.22	68076.940	0.000	68076.900	0.000	0.000	60	K	H	F
SL 15	3.38	17.45	5105.050	0.000	5105.050	0.000	0.000	30	K	H	F

Table A.3 Accident scenarios for on-site disposal activities at TEAD (continued)

Activity ID[1] and scenario	ML[2] prime distance (Km)	VS[3] prime distance (Km)	Amount of agent released: Total (lb)	Detonated (lb)	Emitted (lb)	Evaporated (lb)	Amount of agent unreleased (lb)	Event duration (min)	Munition type[4]	Agent type[5]	Release mode[6]
SL 16	1.35	5.76	833.681	0.000	0.000	833.681	339625.000	240	K	H	S
SL 18	0.40	1.44	81.283	0.000	0.000	81.283	25527.000	240	K	H	S
HS 11	1.64	5.39	31.477	31.477	0.000	0.000	0.000	60	M	V	C
SL 22	1.64	5.39	31.477	31.477	0.000	0.000	0.000	360	M	V	C
SL 25	1.64	5.39	31.477	31.477	0.000	0.000	0.000	120	M	V	C
HS 5	0.66	2.08	6.622	6.501	0.125	0.000	0.000	60	P	G	C
HS 6	0.79	2.50	9.290	6.501	2.799	0.000	0.000	60	P	G	C
HS 7	1.07	3.48	16.904	13.002	3.899	0.000	0.000	20	P	G	C
HS 11	0.79	2.50	9.290	6.501	2.799	0.000	0.000	60	P	G	C
SL 22	0.79	2.50	9.290	6.501	2.799	0.000	0.000	360	P	G	C
SL 25	0.79	2.50	9.290	6.501	2.799	0.000	0.000	120	P	G	C
HS 7	0.22	0.75	26.915	23.388	3.508	0.000	0.000	20	P	H	C
HS 5	0.72	2.14	5.998	5.998	0.000	0.000	0.000	60	P	V	C
HS 6	0.72	2.14	5.998	5.998	0.000	0.000	0.000	60	P	V	C
HS 7	1.06	3.27	12.882	11.995	0.899	0.000	0.000	20	P	V	C
HS 11	0.72	2.14	5.998	5.998	0.000	0.000	0.000	60	P	V	C
SL 22	0.72	2.14	5.998	5.998	0.000	0.000	0.000	360	P	V	C
SL 25	0.72	2.14	5.998	5.998	0.000	0.000	0.000	120	P	V	C
HS 5	1.09	3.53	17.298	14.488	2.799	0.000	0.000	60	Q	G	C
HS 7	1.39	4.63	28.249	21.727	6.531	0.000	0.000	20	Q	G	C
HS 11	1.09	3.53	17.298	14.488	2.799	0.000	0.000	60	Q	G	C
SL 22	1.09	3.53	17.298	14.488	2.799	0.000	0.000	360	Q	G	C
SL 22	1.12	3.49	14.488	14.488	0.000	0.000	0.000	360	Q	V	C

Table A.3 Accident scenarios for on-site disposal activities at TEAD (continued)

Activity ID[1] and scenario	ML[2] prime distance (Km)	VS[3] prime distance (Km)	Amount of agent released				Amount of agent unreleased (lb)	Event duration (min)	Munition type[4]	Agent type[5]	Release mode[6]
			Total (lb)	Detonated (lb)	Emitted (lb)	Evaporated (lb)					
HS 11	1.36	4.53	27.164	21.380	5.794	0.000	0.000	60	R	G	C
SL 22	1.36	4.53	27.164	21.380	5.794	0.000	0.000	360	R	G	C
SL 25	1.36	4.53	27.164	21.380	5.794	0.000	0.000	120	R	G	C
HS 11	1.32	4.18	19.999	19.999	0.000	0.000	0.000	60	R	V	C
SL 22	1.32	4.18	19.999	19.999	0.000	0.000	0.000	360	R	V	C
SL 25	1.32	4.18	19.999	19.999	0.000	0.000	0.000	120	R	V	C
SL 8	14.18	79.46	4581.419	0.000	4581.420	0.000	0.000	60	S	V	C
SL 15	10.75	53.48	2032.357	0.000	2032.360	0.000	0.000	30	S	V	F
SLA27	10.91	74.03	4497.799	0.000	4497.800	0.000	0.000	360	S	V	F
SLB27	10.91	74.03	4497.799	0.000	4497.800	0.000	0.000	360	S	V	F
SLC27	15.47	>100	8994.976	0.000	8994.980	0.000	0.000	360	S	V	F
SLD27	10.91	74.03	4497.799	0.000	4497.800	0.000	0.000	360	S	V	F
SLE27	10.91	74.03	4497.799	0.000	4497.800	0.000	0.000	360	S	V	F
SLF27	15.47	>100	8994.976	0.000	8994.980	0.000	0.000	360	S	V	F

[1] Activity ID (activity during which accident occurs)
HS = Handling during long-term storage
SL = Long-term storage

[2] MS = most likely meteorological condition of 3 m/s wind speed and D stability.

[3] VS = very stable meteorological condition of 1 m/s wind speed and E stability.

Table A.3 Accident scenarios for storage and handling activities at TEAD (continued)

[4] Munition Type
- B = Bombs
- C = Cartridges (105mm)
- K = Bulk ("ton") containers
- M = Mines
- P = Projectiles (155mm)
- Q = Projectiles (8 in.)
- R = Rockets
- S = Spray tanks

[5] Agent Type
- G = Agent GB ("Sarin")
- H = Agents H, HT, HD ("Mustard")
- V = Agent VX

[6] Release Mode
- C = Complex mode (including combinations of simple modes and indoor releases affected by building systems)
- F = Fire (incomplete combustion)
- S = Spill (leading to partial evaporation)

Table A.4 Scenario descriptions for accidents during storage and handling activities at TEAD

Activity code & scenario ID	Scenario description
HS 001	Drop of pallet or container in storage area or maintenance facility; munition punctured.
HS 002	Forklift collision with short duration fire.
HS 003	Forklift tine puncture.
HS 004	Forklift collision without fire.
HS 005	Drop of munition leads to detonation.
HS 006	Collision accident leads to detonation.
HS 007	Collision accident with prolonged fire.
HS 008	Munition pallet dropped during pallet inspection.
HS 009	Forklift tine puncture during pallet inspection.
HS 010	Forklift collision during pallet inspection.
HS 011	Munition pallet dropped during pallet inspection; detonation occurs.
SL 002	Munition punctured by forklift tine during leaker-handling activities.
SL 007	Severe earthquake breaches the munitions in storage igloos, no detonations.
SL 008	Meteorite strikes the storage area; fire occurs; munitions breached (if burstered, detonation also occurs).
SL 009	Munition dropped during leaker isolation operation, munition punctured.

Table A.4 Scenario descriptions for accidents during storage and handling activities at TEAD (continued)

Activity code & scenario ID	Scenario description
SL 015	Small aircraft direct crash onto warehouse or open storage yard, fire occurs, not contained in 30 min.
SL 016	Large aircraft direct crash, no fire, detonation (if burstered).
SL 018	Small aircraft direct crash onto warehouse or open storage yard, no fire.
SL 022	Severe earthquake leads to munition detonation.
SL 025	Munition dropped during leaker isolation, munition detonates.
SL A27	Earthquake occurs, TEAD warehouses intact, munitions intact, fire occurs at one warehouse.
SL B27	Earthquake occurs, TEAD warehouses intact, munitions intact, fire occurs at two warehouses.
SL C27	Earthquake occurs, one TEAD warehouse is damaged, munitions intact, fire occurs at one warehouse.
SL D27	Earthquake occurs, one TEAD warehouse is damaged, munitions intact, fire occurs at two warehouses.
SL E27	Earthquake occurs, two TEAD warehouses damaged, munitions intact, fire occurs at one warehouse.
SL F27	Earthquake occurs, two TEAD warehouse damaged; munitions intact; fire occurs at two warehouses.

APPENDIX B

DISTRIBUTION OF METEOROLOGICAL CONDITIONS NEAR THE TEAD-S AREA

APPENDIX B

DISTRIBUTION OF METEOROLOGICAL CONDITIONS NEAR THE TEAD-S AREA

This appendix contains graphs showing the distribution of wind directions and atmospheric stabilities for separate wind speed classes. These wind speed classes, which correspond to monitored data in the TEAD-S area, are:

1. less than 2.1 m/s (4.7 mph)
2. between 2.1 and 3.6 m/s (4.7 - 8.1 mph)
3. between 3.6 and 5.7 m/s (8.1 - 12.8 mph)
4. between 5.7 and 8.7 m/s (12.8 - 19.5 mph)
5. between 8.7 and 10.8 m/s (19.5 - 24.2 mph)
6. greater than 10.8 m/s (greater than 24.2 mph)

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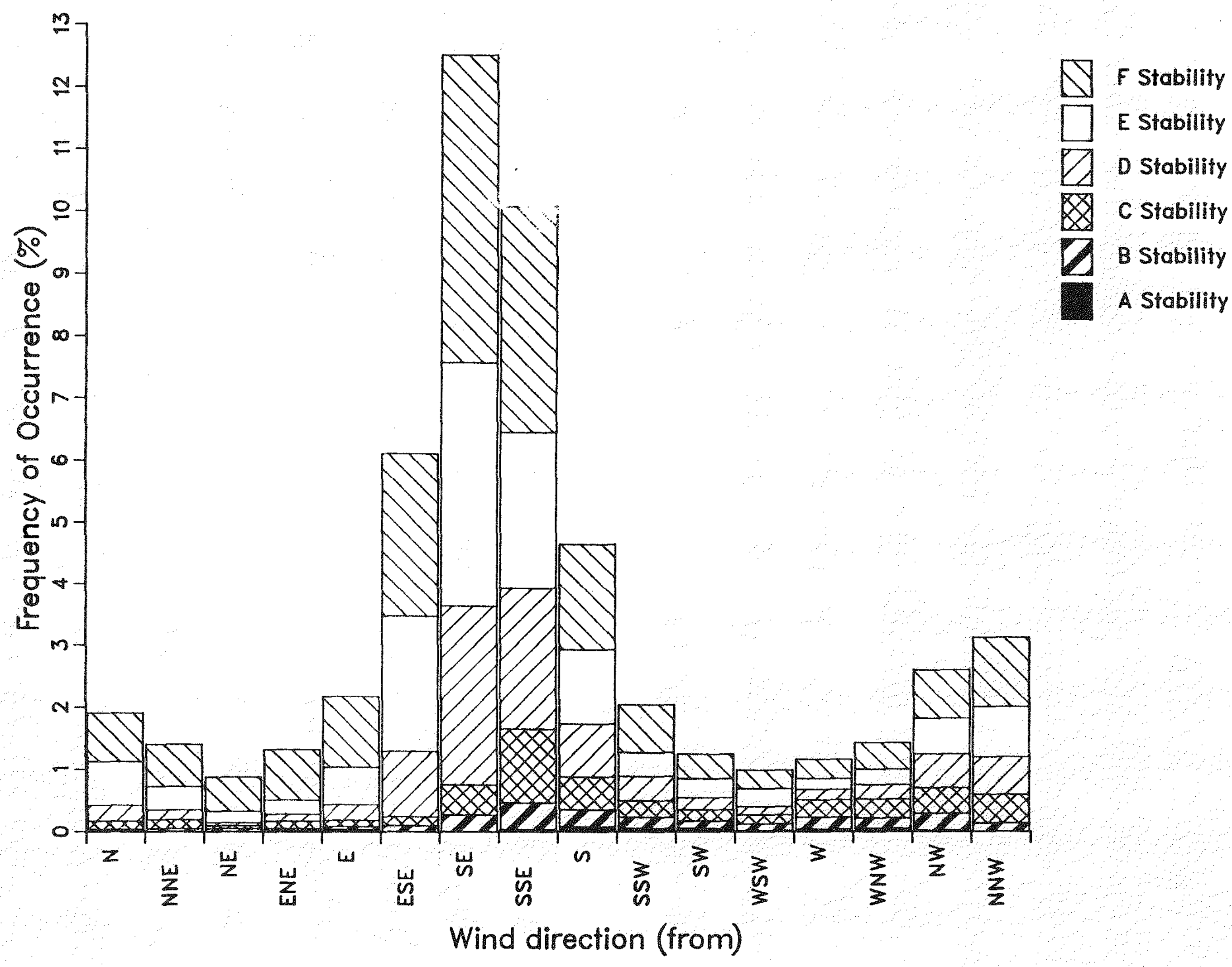

Fig. B.1 Distribution of wind directions and stabilities for winds <2.1 m/s (TEAD data, Nov. 1986-Oct. 1987)

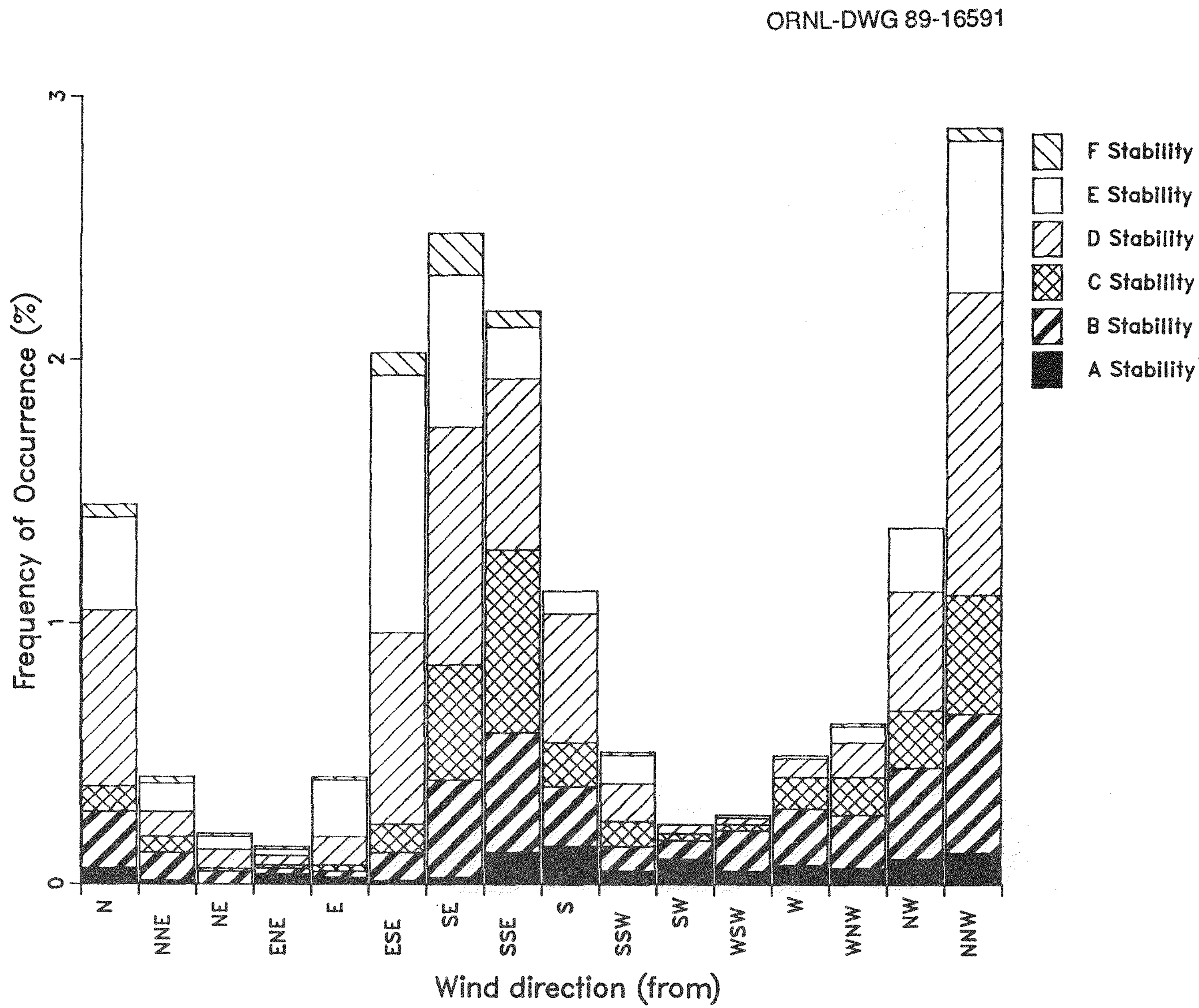

Fig. B.2 Distribution of wind directions and stabilities for winds 2.1-3.6 m/s (TEAD data, Nov. 1986-Oct. 1987)

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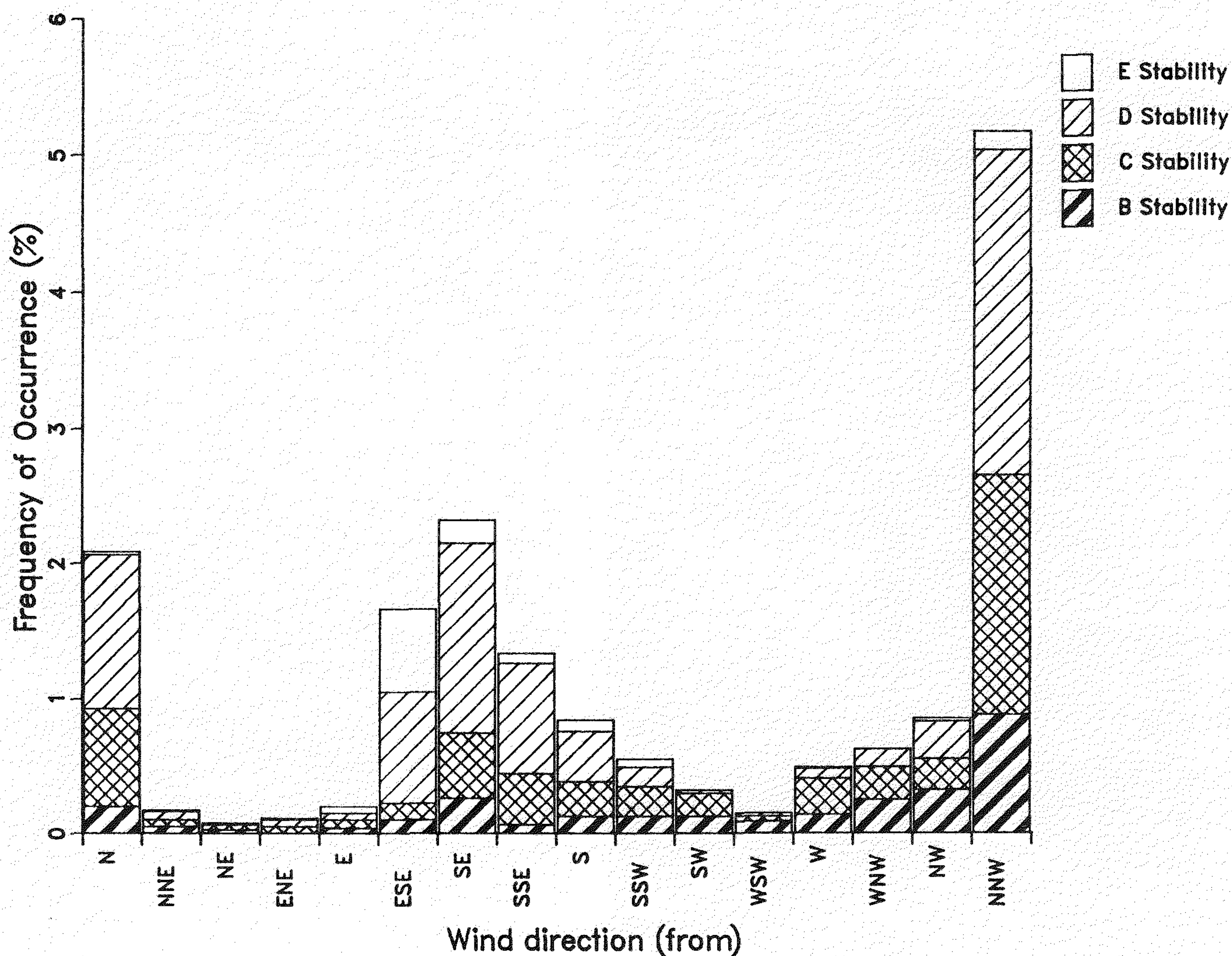

Fig. B.3 Distribution of wind directions and stabilities for winds 3.6-5.7 m/s (TEAD data, Nov. 1986-Oct. 1987

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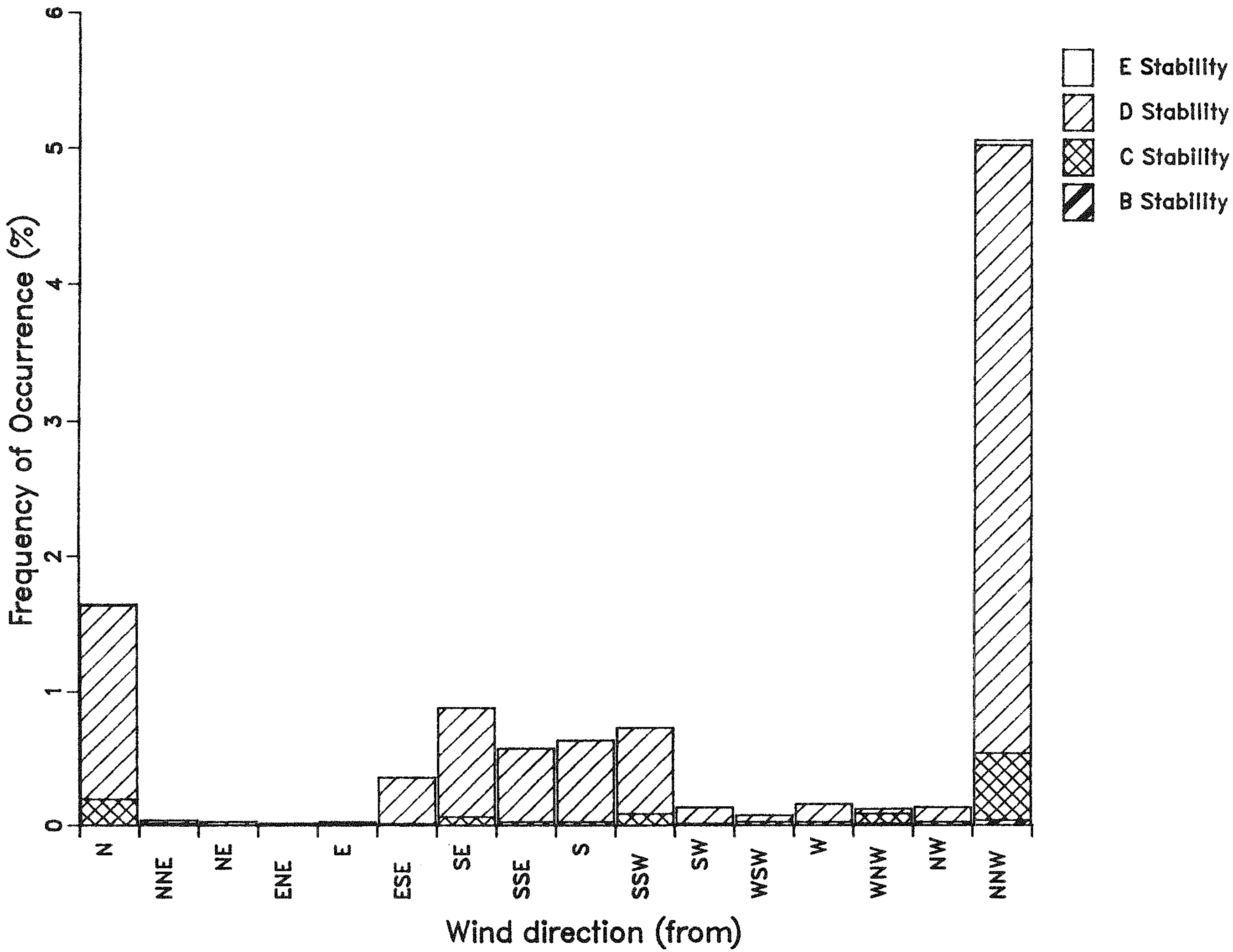

Fig. B.4 Distribution of wind directions and stabilities for winds 5.7-8.7 m/s (TEAD data, Nov. 1986-Oct. 1987)

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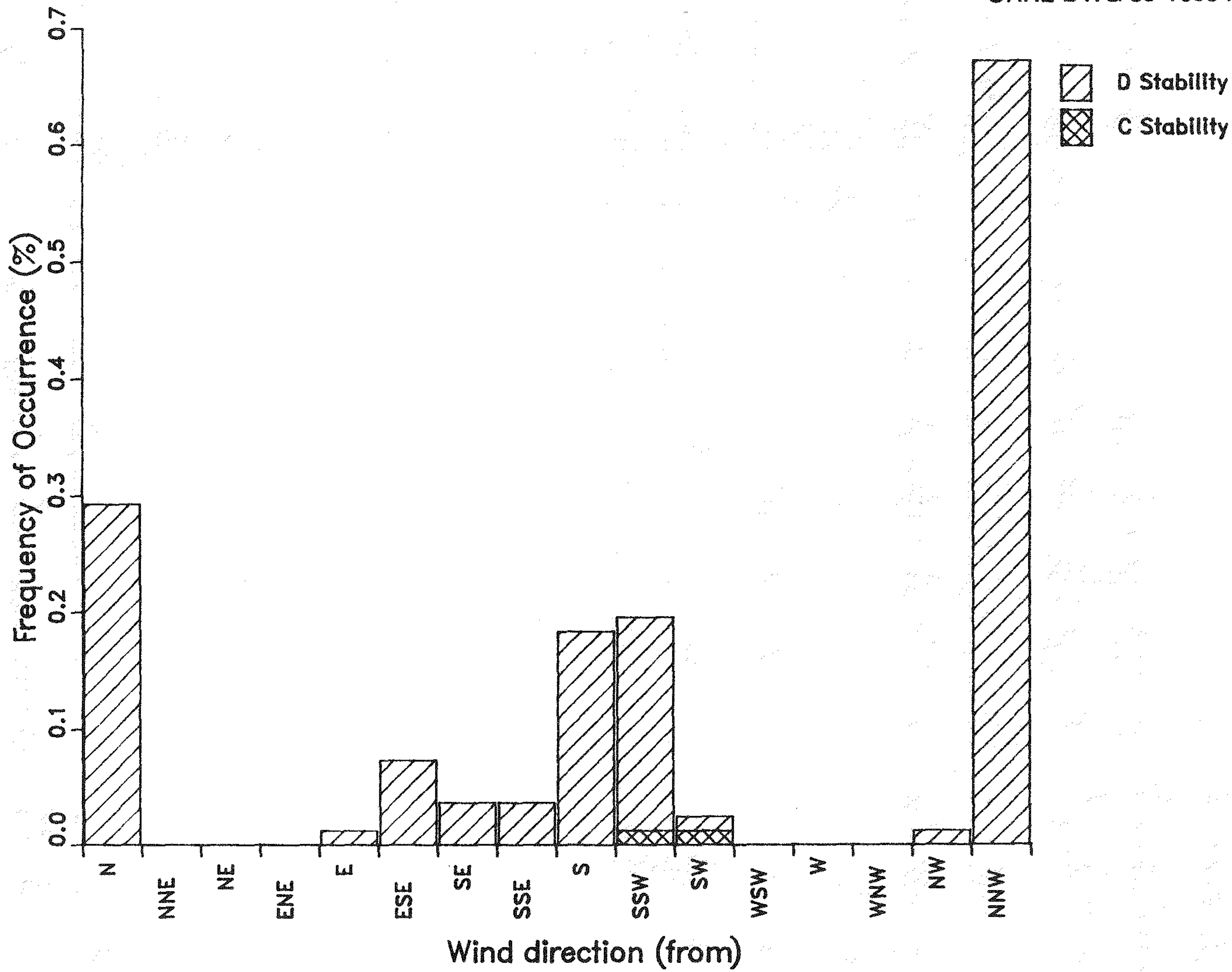

Fig. B.5 Distribution of wind directions and stabilities for winds 8.7-10.8 m/s (TEAD data, Nov. 1986-Oct. 1987)

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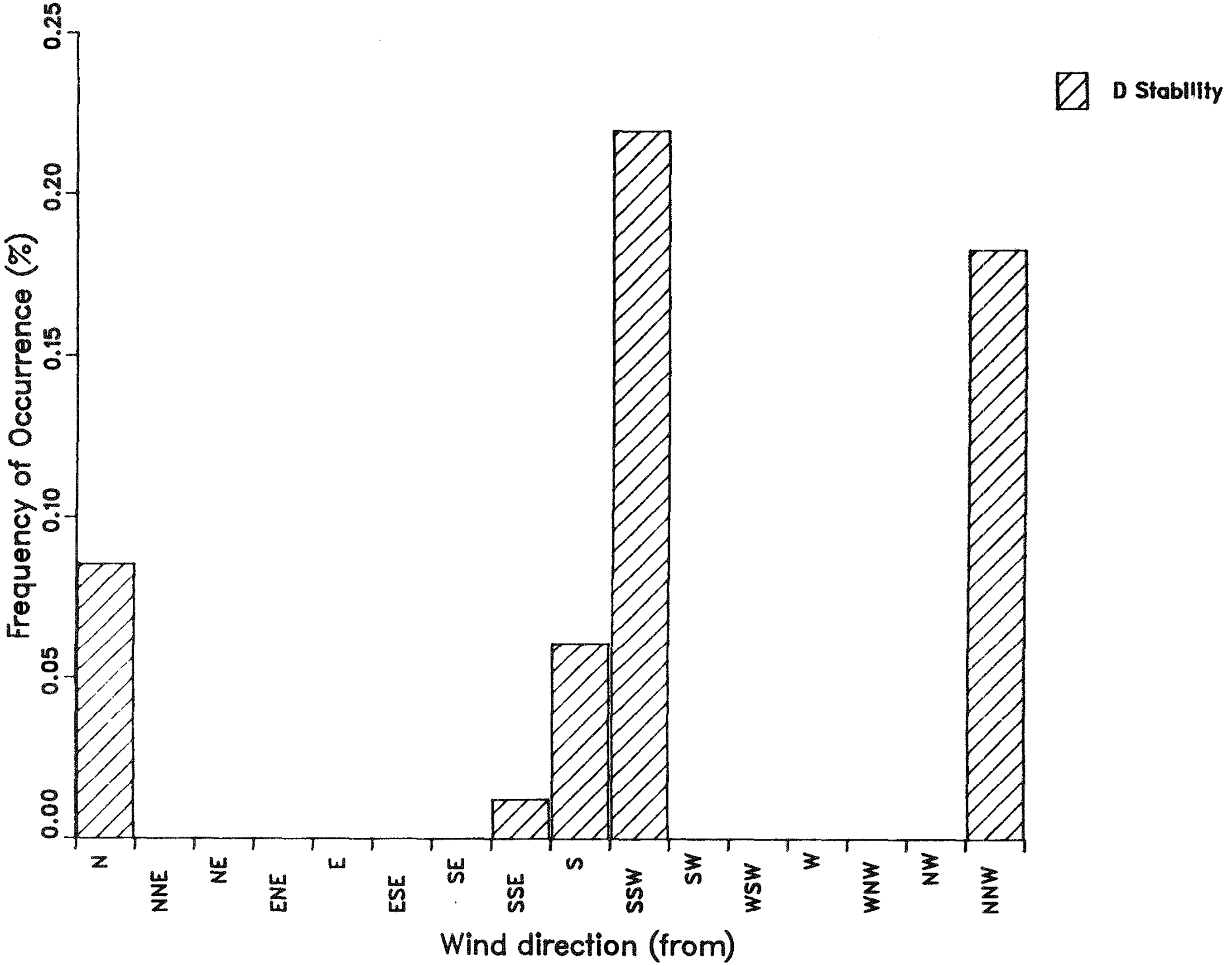

Fig. B.6 Distribution of wind directions and stabilities for winds >10.8 m/s (TEAD data, Nov. 1986-Oct. 1987)

APPENDIX C

HOSPITALS IN COUNTIES WITHIN 100 km OF TOOELE ARMY DEPOT-SOUTH

TABLE C.1 Hospitals in counties with area within 100 km of TEAD-S

Hospital	Community	County	Beds	Occupancy Rate (%)	Distance (km)	Direction
American Fork	American Fork	Utah	72	63.9	48	ENE
Cottonwood Hospital Med. Center	Murray	Salt Lake	243	54.7	58	NE
Central Valley Med. Center	Nephi	Juab	31	19.4	80	SSE
Mountain View Hospital	Payson	Utah	118	58.4	60	ESE
Utah State Hospital*	Provo	Utah	318	93.1	60	E
Utah Valley Regional Med. Center	Provo	Utah	336	69.3	60	E
Holy Cross Hospital	Salt Lake City	Salt Lake	293	66.9	65	NNE
LDS Hospital	Salt Lake City	Salt Lake	468	69.7	65	NNE
Primary Childrens Med. Center	Salt Lake City	Salt Lake	173	83.2	65	NNE
Shriners Hosp./Crippled Children	Salt Lake City	Salt Lake	45	53.2	65	NNE
St. Marks Hospital	Salt Lake City	Salt Lake	306	63.7	65	NNE
Univ. of Utah Health Sciences	Salt Lake City	Salt Lake	370	71.1	65	NNE
Veterans Admin. Med. Center	Salt Lake City	Salt Lake	392	66.7	65	NNE
Alta View Hospital	Sandy	Salt Lake	50	64.0	50	NE
Tooele Valley Hospital	Tooele	Tooele	33	33.3	27	N
Pioneer Valley Hospital	West Valley City	Salt Lake	139	46.8	65	NNE

* Psychiatric hospital

Sources: American Hospital Association Guide to the Health Care Field and U.S. Department of the Interior, Geological Survey Map.

APPENDIX D

RELATIONSHIPS AMONG SOURCE TERMS, METEOROLOGICAL CONDITIONS, AND LETHAL DOWNWIND DISTANCES

APPENDIX D

RELATIONSHIPS AMONG SOURCE TERMS, METEOROLOGICAL CONDITIONS, AND LETHAL DOWNWIND DISTANCES

At the time of a chemical agent release it is essential to know how far a lethal plume might travel so that appropriate warnings can be made and appropriate protective actions can be recommended. This knowledge depends on both the release characteristics (i.e., agent type, size, and mode of release) and prevailing meteorological conditions (i.e., wind speed, wind direction, and atmospheric stability). To the extent possible, it is desirable to know in advance the relationships among these variables so that precious time is not spent performing analyses fundamental to making public alert and protective action recommendations. This appendix is an initial attempt to provide some of this analysis.

The following graphs were developed using the Army's D2PC atmospheric dispersion code. They do not account for the effects of any site-specific topography, vegetation, or meteorology (e.g., prevailing wind direction, speed, or atmospheric stability) on resultant downwind lethal distances (see Sect. 3 of this report). They show the relationships between agent type, mode of release, source size, wind speed, and downwind lethal distance. There is a separate graph for each agent type/release mode pair. Within each of these figures, the graph displays the log-log relationship between source size and lethal downwind distance. From these graphs one can determine how much agent is required to result in a given lethal downwind distance under 3 sets of meteorological conditions. These three sets of conditions are as follows:

1 m/s (2.2 mph) at E atmospheric stability
3 m/s (6.7 mph) at D atmospheric stability
6 m/s (13.4 mph) at D atmospheric stability

In reading these graphs the reader should be alert to the log-log scales and interpolate between expressed values very cautiously.

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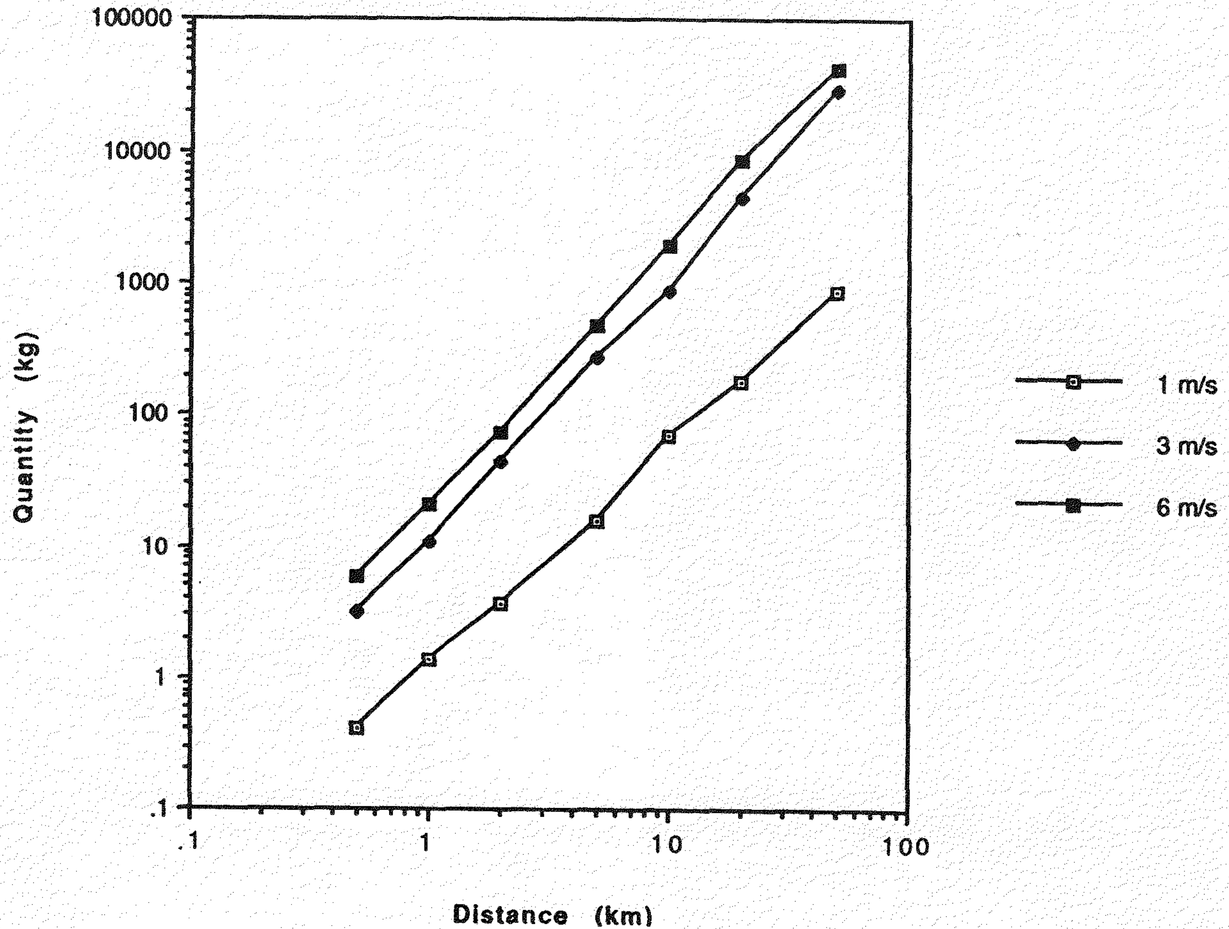

Fig. D.1. VX agent, semi-continuous release.

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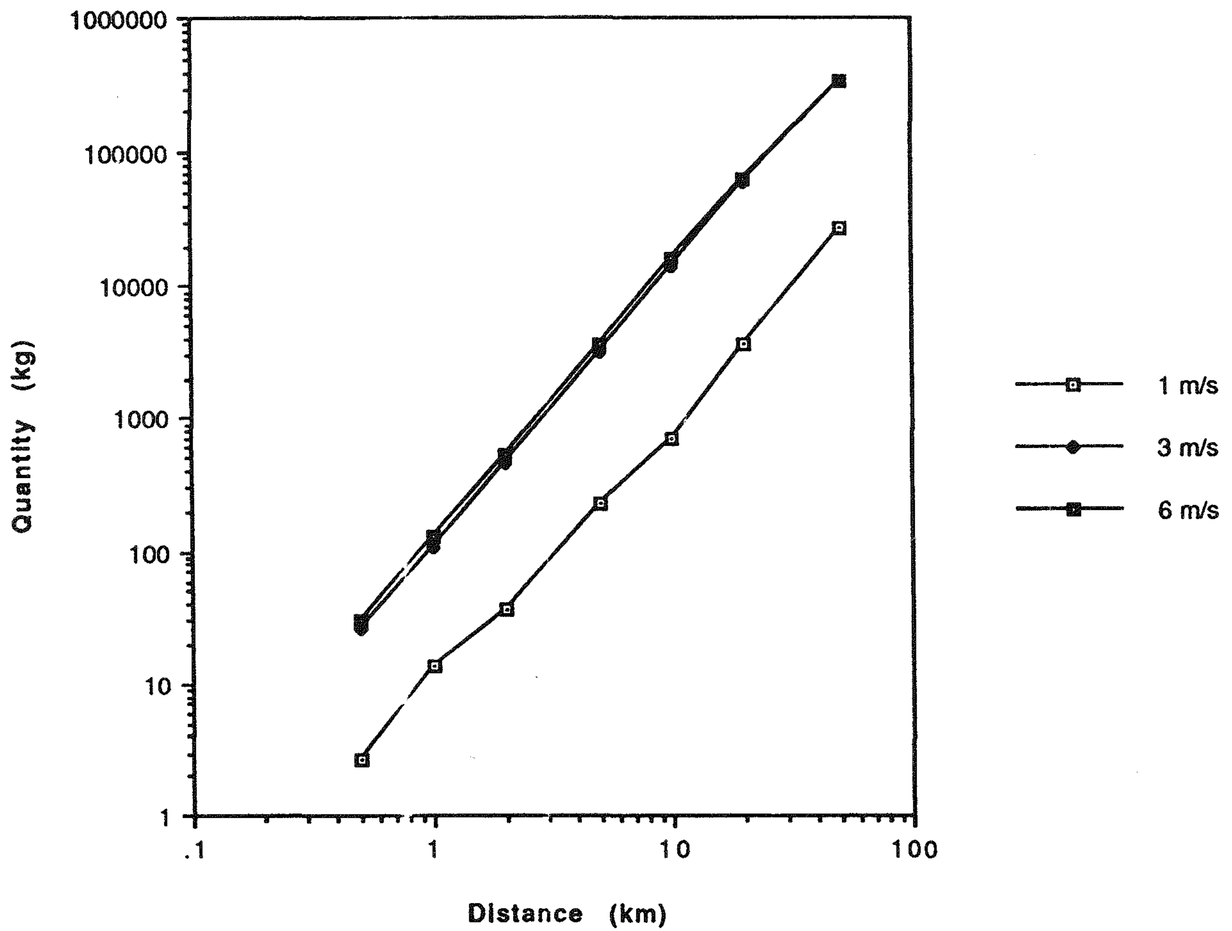

Fig. D.2. GB agent, continuous (evaporation/spill) release.

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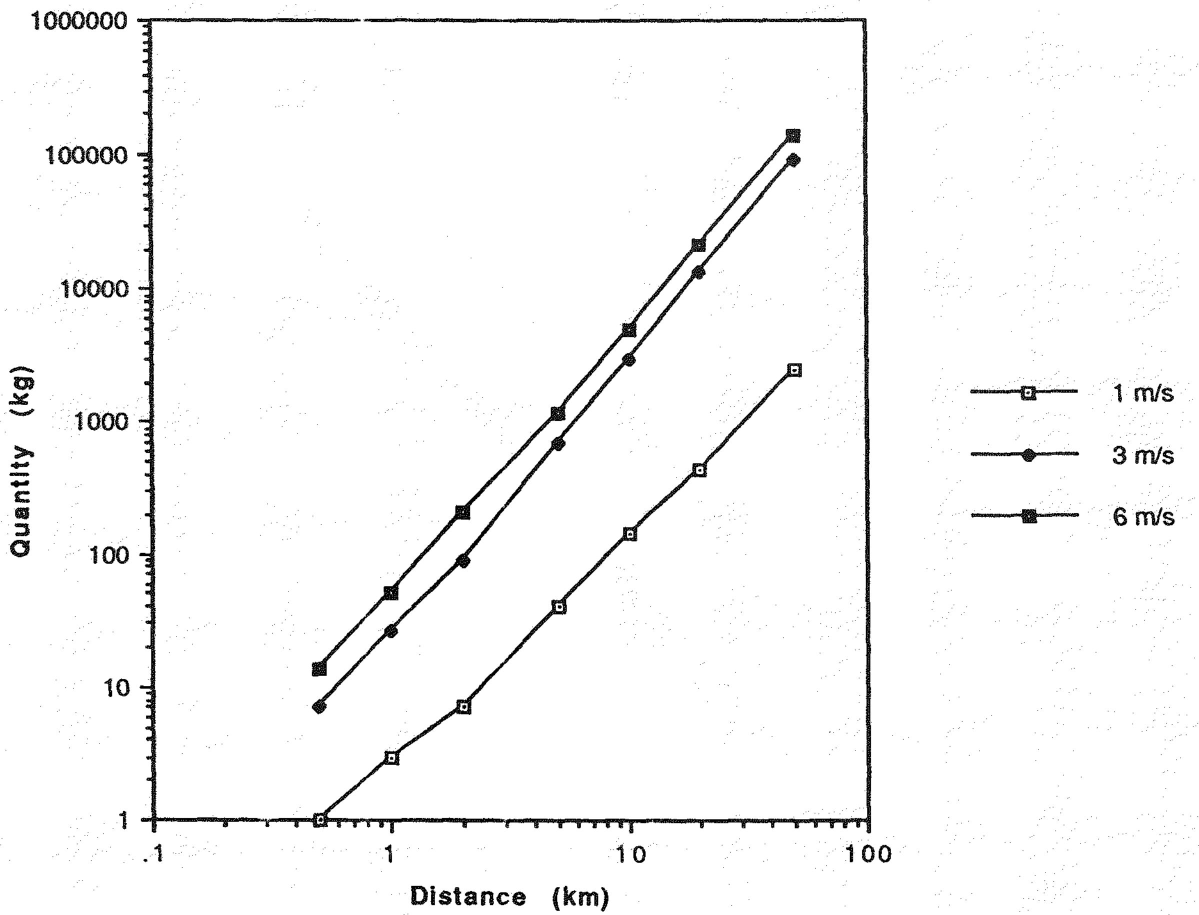

Fig. D.3. GB agent, semicontinuous release.

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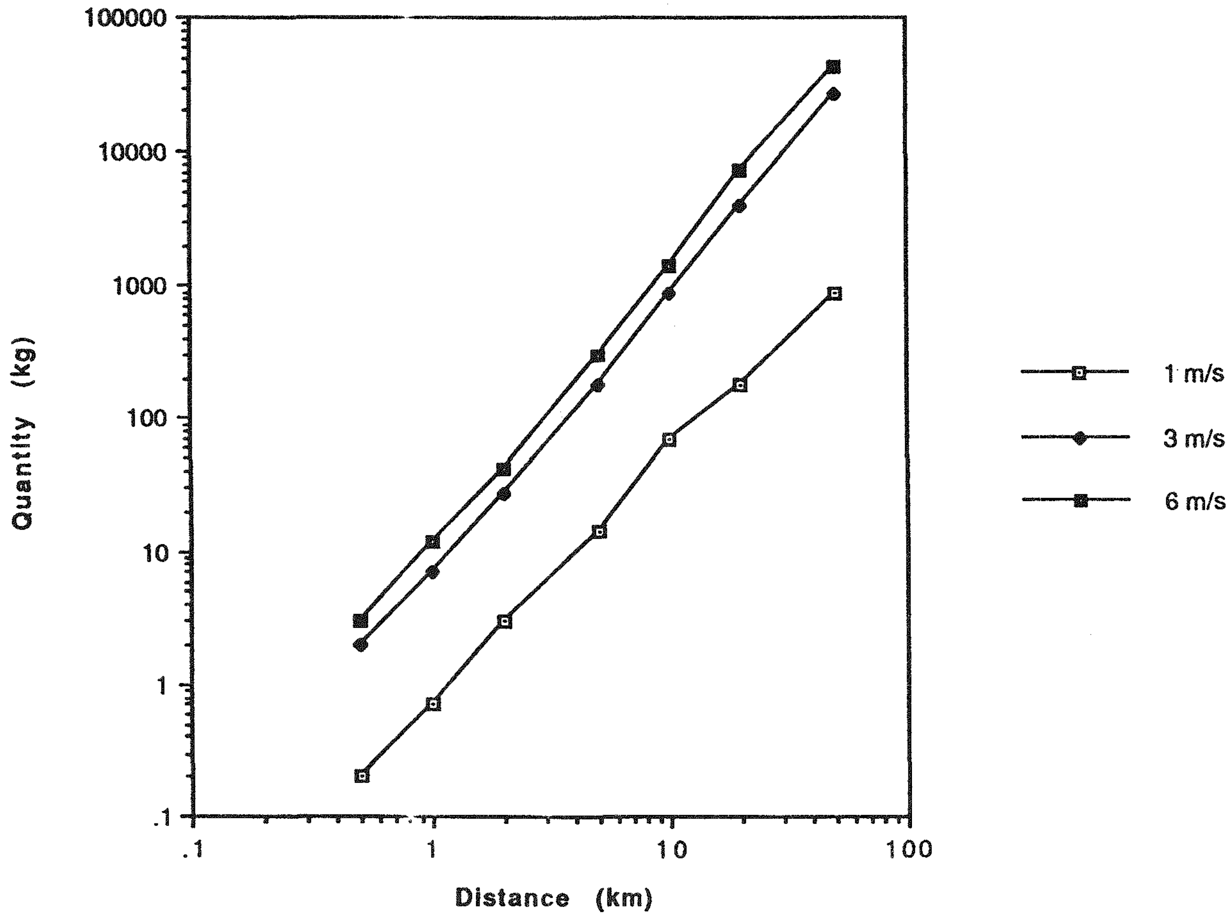

Fig. D.4. GB agent, instantaneous release.

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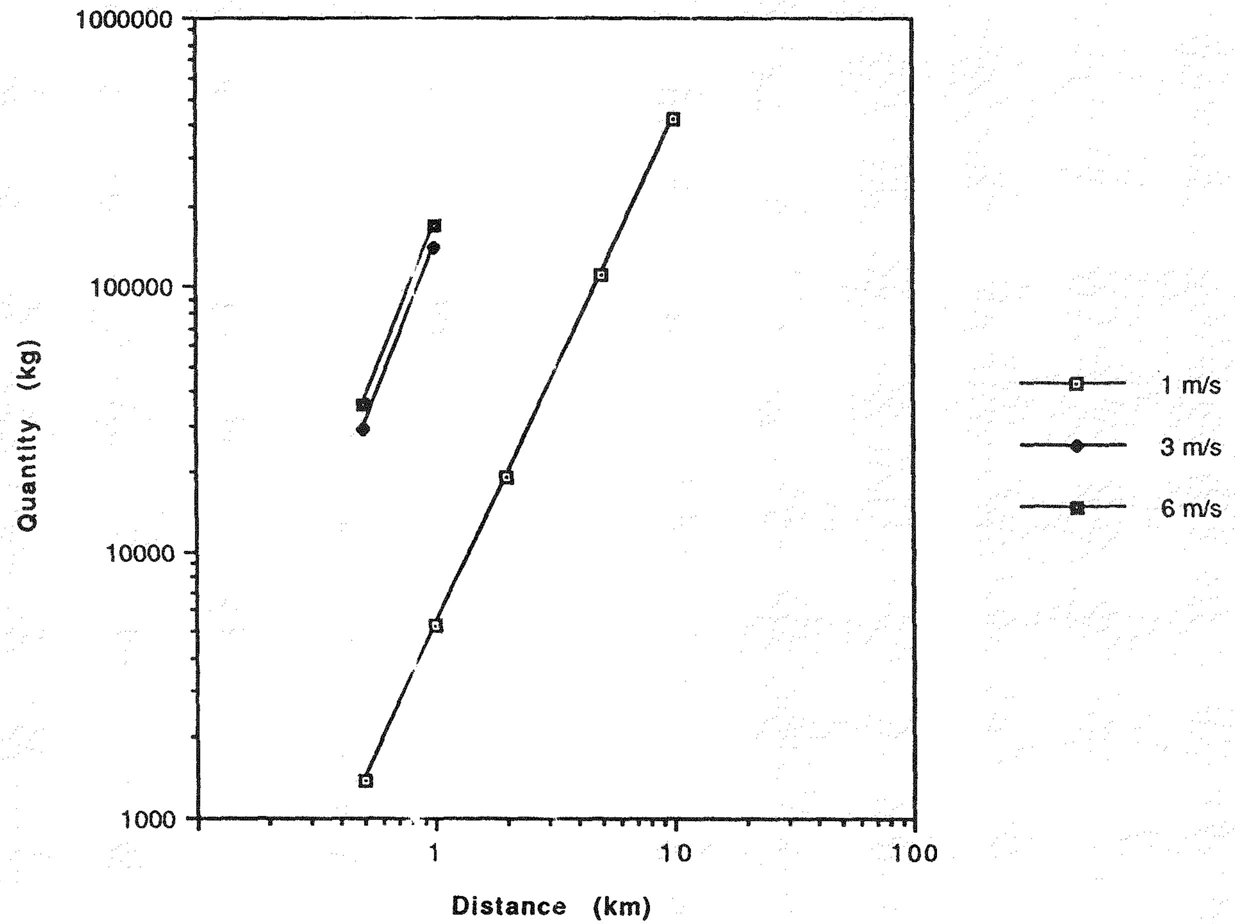

Fig. D.5. HD agent, continuous (evaporation) release.

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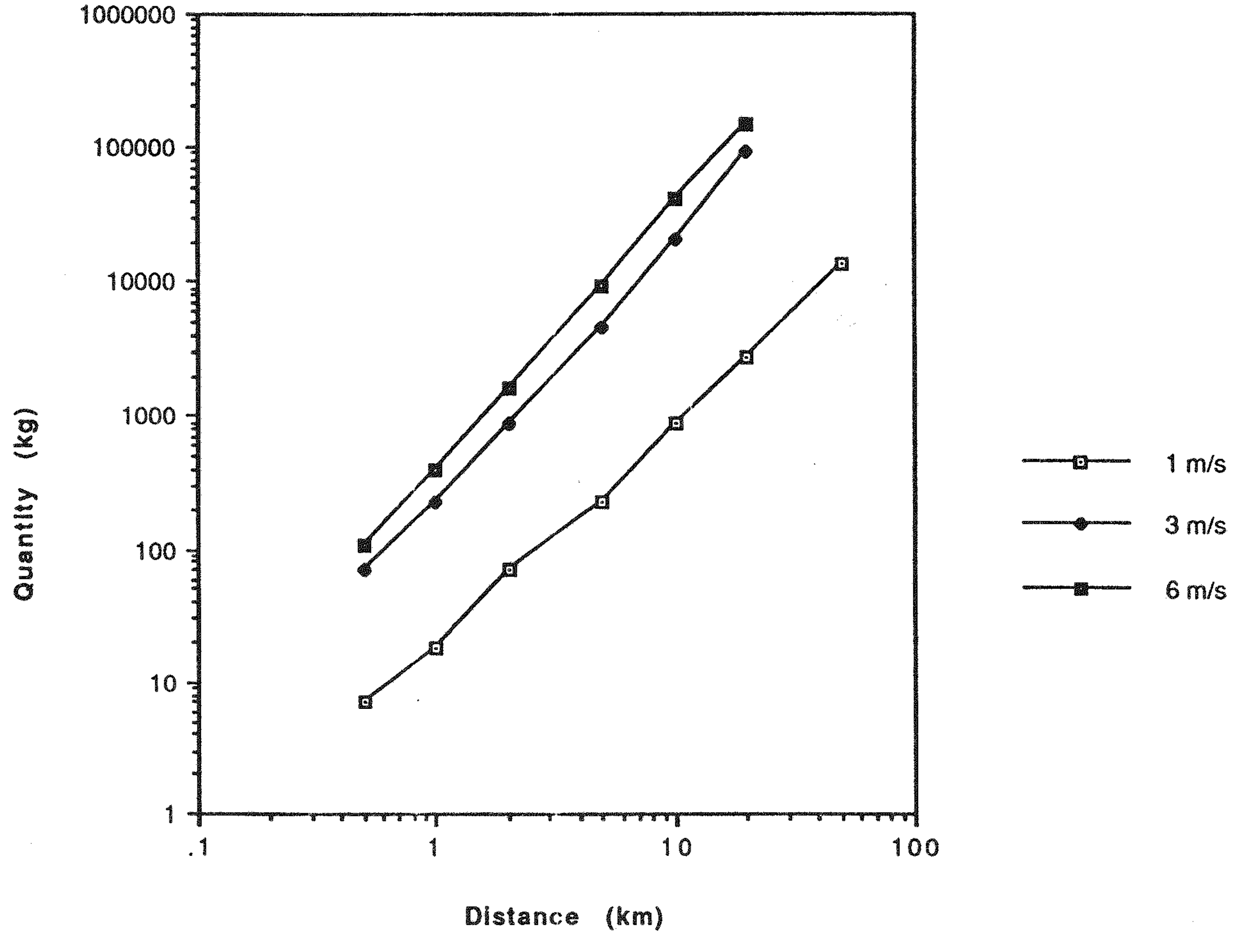

Fig. D.6. HD agent, semicontinuous release.

APPENDIX E

MAJOR PROGRAM DECISIONS

APPENDIX E

MAJOR PROGRAM DECISIONS

<u>Emergency Planning Zones</u>

How many zones are appropriate for the site?
What is the basis for setting distances?
What distances should they extend to?

<u>Accident Assessment</u>

What mechanism will be used to detect releases?
How will accidents be classified?
How will source terms be estimated?
What meteorological data are needed?
What dispersion code will be used?
What resources and equipment are needed to support the code?
Who will make the assessment?
How will assessment results be communicated?

<u>Command and Control</u>

Who is in charge initially?
Who assumes control?
Do Army regulations allow a different decision process than the current one?
What command/control system will be used?
Will the communities give the Army authority to warn the public?
What Emergency Operations Center (EOC) will be used?
What is the backup EOC?
Is EOC equipment adequate?

<u>Protective Action Options</u>

What options will be considered and utilized?
What hardware and resources are needed to support options?
What installation is needed?
What will be distributed to the public?
What information/training is needed?

<u>Protective Action Decision Making</u>

Who will make the decision?
Will protective action guides be established?
Will the process be automated?

Communications

Who will be included in the communications network?
Who will be the backups?
What equipment is nedded to implement network?
Will a standardized information protocol be used?

Public Warning

Who decides to issue the warning?
What is the warning source?
What is the content of the warning?
What warning system will be used?
What areas will be covered?
What equipment will be purchased and installed?
What is the strategy for rumor control?

Traffic Control

What areas will be isolated?
What traffic control equipment is needed?
What are the personnel needs?
What equipment is needed?

Worker Protection

Which workers will require protection?
What equipment is needed to provide that protection?

Special Populations

What special populations exist at a site?
How will different groups be warned?
How will special populations be protected?
What equipment is needed?

Medical Services

What level of service is needed?
What resources are needed to support that level?
How will search and rescue be conducted?
How will decontamination of injured be managed?
How will body handling be performed?

Transportation

What needs for transportation exist?
Are resources needed to supplement existing equipment?
How will people be evacuated?

Information Management

What functions require an information management system?
What resources are needed?

Mass Care

What is the need for shelter for evacuees?
How will people be monitored for exposure?
What decontamination capabilities are needed?
What additional resources (food, clothing) are needed?

Reentry

How will the accident area be monitored?
How will food and water be tested?
What criteria will be used to determine safety of area?
Who makes the reentry decision?

Preparedness

What types of public information are needed?
What types of worker training are needed?
What pre-emergency agreements are needed?
What standard operating procedures (SOPs) are needed?
How will preparedness be exercised and tested?

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