ORNL/TM--9692

DE86 001466

ENERGY DIVISION

EVACUATION DECISION-MAKING: PROCESS AND UNCERTAINTY

Dennis Mileti*
John Sorensen
William Bogard*

*Colorado State University

Date Published: September 1985

Prepared for the
Office of Nuclear Safety
U.S. Department of Energy
Washington, D.C. 20545

Prepared by the
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831
operated by
MARTIN MARIETTA ENERGY SYSTEMS, INC.
for the
U.S. DEPARTMENT OF ENERGY
under Contract No. DE-AC05-840R21400

CONTENTS

CONTENTS (continued)

LIST OF TABLES

ABSTRACT

The purpose of this study was to describe the processes of evacuation decision-making, identify and document uncertainties in that process and discuss implications for federal assumption of liability for precautionary evacuations at nuclear facilities under the Price-Anderson Act. Four major categories of uncertainty are identified concerning the interpretation of hazard, communication problems, perceived impacts of evacuation decisions and exogenous influences. Over 40 historical accounts are reviewed and cases of these uncertainties are documented. The major findings are that all levels of government, including federal agencies experience uncertainties in some evacuation situations. Second, private sector organizations are subject to uncertainties at a variety of decision points. Third, uncertainties documented in the historical record have provided the grounds for liability although few legal actions have ensued. Finally it is concluded that if liability for evacuations is assumed by the federal government, the concept of a "precautionary" evacuation is not useful in establishing criteria for that assumption.

1. INTRODUCTION

1.1 UNCERTAINTIES IN EVACUATION DECISION MAKING

The historical record of evacuations clearly illustrates that uncertainties have, on occasion, affected all aspects of evacuation decision making. The consequences of these uncertainties have been varied in past evacuation cases; they range from the insignificant to those contributing toward increased loss of life and property associated with particular disasters. This work has assembled and catalogued uncertainties in the evacuation decision-making process from existing evacuation research.

Research suggests that uncertainties fall into four general categories. First, uncertainties have been documented in reference to how people and organizations interpret threatening situations and their roles in the evacuation decision-making process. Specifically, uncertainties have surfaced to constrain sound evacuation decision making because of interpretation of the hazard, hazard information obtained directly or through others, and in reference to who is to do what as part of the decision-making process. Second, uncertainties in reference to communications have been numerous in the record of past evacuations. Evacuation decision making includes a multitude of different actors and organizations at varied governmental levels. Uncertainties have prevailed in a number of evacuations over whom to communicate with, as well as when and how that communication might occur. Third, evacuation decision makers have, on occasion, been a source of uncertainties themselves;

concern over the impacts of their decisions -- whether these concerns are warranted or are unfounded -- have constrained sound evacuation decision making and been a source of uncertainty in the evacuation decision process. For example, concerns have included fear of public panic, the costs of an unnecessary evacuation and so on. Finally, a set of factors exogenous to the evacuation decision-making process has surfaced to inject uncertainty into decision making; for example, the state-of-the-art in the sciences which are used to predict the impact of a disaster. These four uncertainty categories -- interpretation, communication, perceived impacts, and exogenous influences -- are elaborated on in greater detail in the body of this report.

1.2 THE GENERAL EVACUATION DECISION-MAKING PROCESS

All evacuations are in some ways unique. Nevertheless, each consists of a general set of activities and decision points that are largely common to all evacuations. Common activities to all evacuations, for example, are detecting that a hazard and threat exists for a population; making the decision to alert those who would be responsible for public safety; making the decision that evacuation is the recommended protective action; and carrying the warning and advisement to the public. Obviously, the process includes decision points and communications. Often, formal channels have been supplemented or replaced by informal ones. Occasionally, steps in the process are by-passed.

2. THE EVACUATION DECISION-MAKING PROCESS

The uncertainties that have risen to affect historical evacuations are clearly better viewed in terms of what aspect of the general decision-making process that they affected than they are viewed on their own. Consequently, this section illustrates and defines the general components, common decision points and processes that are somewhat characteristic of all evacuations. These common points and processes are schematically represented in Figure 1. Key decision points are represented by boxes in the figure, and key linkages between decisions (communications) are indicated by arrows. Uncertainty and ambiguity can exist at each key decision point and at each communication link. The particular actors and organizations involved with each decision, as well as, who actually participates in the communications process will vary given the actual evacuation examined. In some cases, it could be a single actor or agency; in others it could include a diverse set of people, groups, and organizations. The purpose of this section is to define and explain, in a general way, each decision point and linkages between organizations involved in these points in the evacuation decision process illustrated in Figure 1. Examples are also given of the kinds of actors and organizations who would typically be involved in the process.

ORNL-DWG 85-14964

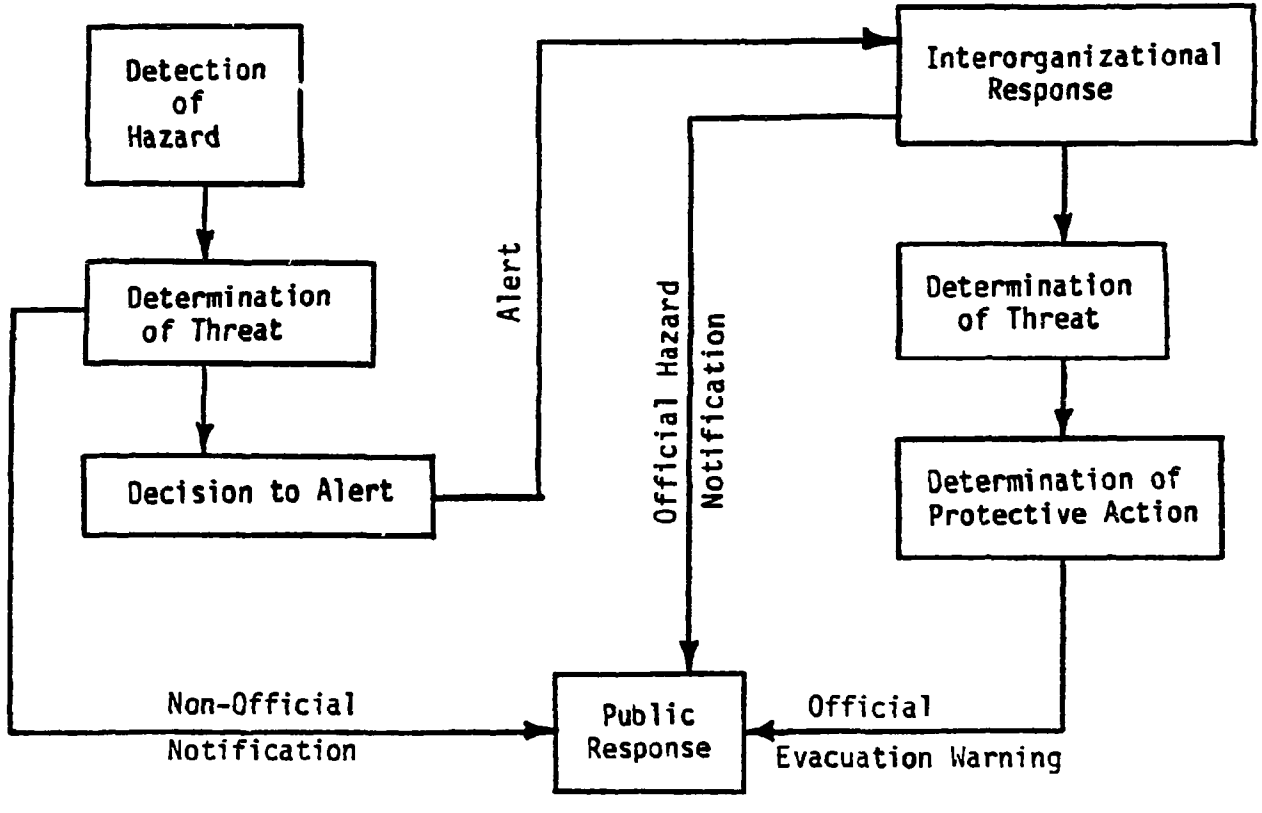

Figure 1. Evacuation decision process

2.1 KEY DECISION POINTS

2.1.1 Detection of Hazard

The initial stage of any public evacuation is the recognition that a particular event or situation constitutes a hazard. In a flood, for example, event recognition may be rain and rising river levels. At a nuclear power plant, it may be a combination of instrument readings and alarms. For an earthquake, it may be unusual animal behavior or swarms of small precursory seismic events. Regardless of the type of hazard, some signs must be read and interpreted to mean that a hazard exists before evacuation is turned to as a possible protective action. Detection may be made by a member of the public (as in the case of a hazardous chemical spill from a truck) or by a complex organization set up to look for and detect hazards. For example, the National Weather Service detects severe storms and tracks hurricanes. The United States Geological Service (USGS) monitors volcanoes for signs of impending eruptions. Some state governments have programs to detect potential landslide hazards. Chemical companies often have monitors at storage facilities to detect releases of hazardous materials.

2.1.2 Determination of Threat

Once a hazard is detected the second key decision in the general process is whether or not it poses a threat to human health and safety. In a flood, this may be defined as waters exceeding flood stage elevations. At a nuclear power plant, it may be defined as some off-site

release. In an earthquake, threat may be indicated by an expected Richter magnitude of energy release and associated shaking intensities in populated areas. Often the determination of threat is done by the same person or organization detecting the hazard; at other times, different actors and organizations may be involved. A private citizen or company of any level of government may determine that a threat exists. The U.S. Geological Survey is, for example, formally charged with issuing hazard watches and must detect and assess threats from geologic hazards. The State of California determines whether or not an earthquake prediction is valid and constitutes a threat to the public. Local governments often must determine whether a derailed train carries hazardous materials. Public and private utilities must determine dose projections in the event of a nuclear power plant accident. Threat determination is judging that an event is or is not hazardous to the public.

2.1.3 Decision to Alert

Once a threat is judged to be a significant one, the detector/assessor must decide whether or not to alert others of the risk and potential damages. Part of this decision includes determining who should receive the alert. In an earthquake, a scientist would need to decide whether or not to make an announcement to the governor or keep silent. For nuclear power plant accidents, guidelines and requirements usually spell out when and who should be alerted. Clearly, for some hazards the alert decision is spelled out in plans while for others it remains discretionary.

2.1.4 Interorganizational Notification

Following an alert, that person or organization receiving the alert must decide which other parties will be involved in the decision to evacuate or implement other types of protective actions. This decision is more important than it may appear on the surface because the number and type of actors involved will affect the timing and outcome of the decision, particularly if a distinct or clear-cut threatening situation is not present.

The actors involved will depend on the hazard, the location and existing emergency plans. In some cases, notification is fixed and automatic; in others, it is largely ad hoc and may depend on who is available at the moment. Often participation emerges during the onset of the hazard with both the formal and informal involvement of actors and organizations in the process.

2.1.5 Determination of Threat

An official decision first must be reached as to whether or not the event poses a hazard to the public. The decision includes determining the magnitude and characteristic of the threat, the locations that would be impacted, and the nature of human exposure to the threat. This decision may be made by a single organization or may be made by a group that forms following the inter-organizational notification.

2.1.6 Determination of Protective Action

Once a hazard is judged to be a significant threat to the public, a decision must be reached as to whether public protective actions are necessary, and what protective action to recommend or implement. This will be determined, in part, by the severity of the threat and the amount of time to its impact. Other factors may also play a role which may not relate to the threat per se. As in the case of threat-assessment, a variety of groups or persons can be involved in this determination.

2.2 KEY COMMUNICATIONS LINKS

2.2.1 Detectors to Officials: Alert

Following the detection of a hazard, information is usually passed on to an agency with emergency powers or responsibilities. This may be a phone call to a police dispatcher, an automatic ring-down to a civil defense director, activation of a tone-alert radio in the mayor's home, and so forth.

2.2.2 Detectors to the Public: Non-Official Notification

Information about the threat may also go directly to the public either simultaneously, before, or after the officials are alerted. The NWS may flash a severe storm warning on television. A person discovering a chemical spill may run door-to-door notifying neighbors.

2.2.3 Interorganizational Alert

This communication link ties together those that will be involved in the official evacuation decision. It may be a series of telephone calls to people on a list in an emergency plan, a siren or whistle in an industrial plant, or informal word-of-mouth communication between people.

2.2.4 Officials to Public: Notification

Prior to a protective action decision, the public may be alerted by officials about an approaching or impending hazard. This alert may be through a media report, activation of an emergency broadcasting system, the sounding of a siren, or interpersonal communications.

2.2.5 Officials to Public: Evacuation Warning

Finally, if evacuation is recommended, officials must inform the public to evacuate and supply them with the details about the evacuation. This may be done over electronic media, with bull horns, or by door-to-door contact.

2.3 AGENCY INVOLVEMENT

A variety of private, local, state, and federal organizations participate in evacuation decision making. The presence, level, and nature of involvement will vary according to the hazard causing the evacuation, the jurisdictional setting and the peculiarities of the event. Table 1 lists agency involvement for generalized evacuation circumstances for

Table 1. Examples of agency involvement in evacuation decision-making

Decision point	Nuclear power plant	Hazard situation		
		Hurricane	Chemical plant	Earthquake
Detection of hazard	Utility	National Weather Service (NWS)	Private company	U.S. Geological Survey (USGS)
Determination of threat	Utility	NWS	Private company	USGS, State Geologists, etc.
Decision to alert	Utility	NWS	Private company	USGS, Governor
Interorganizational Notification	Utility State Highway Patrol	Local NWS office Local Civil Defense (CD)	Local police department	Governor
Determination of threat	State Health Dept., utility, NRC	Local NWS office Local CD	Local CD, CHEMTREC, private company	Board of experts
Decision to evacuate	Utility, State Health Dept., local CD director	Local CD Local mayor	Local CD	Local mayors

four different hazards. These entries are based on legislation, current plans and recent experiences. A review of historical involvement, in general, shows that it is often impossible to predict prior to an evacuation which levels of government and which types of agencies will be involved.

This section has provided a generic model of evacuation decision making and some notion of the agencies involved in that process. The following section will provide a more detailed account of the uncertainties in decisions and parties involved with specific historical evacuations.

1.3 PURPOSE

This work describes the steps and processes of evacuation decision making; documents evacuation events, key decision points and relevant actors and organizations which are part of the general evacuation process; and identifies uncertainties that have risen in the historical record of evacuations to constrain sound evacuation decision making and/or evacuation effectiveness. The objectives are then brought to bear for any implications we see for evacuation coverage for liability under the Price-Anderson Act.

3. UNCERTAINTIES IN EVACUATION DECISIONS

In this section we review the various uncertainties that can affect evacuation decision making. This is done from both a general perspective and an event-specific perspective. This provides information on how evacuation decisions are made, the problems that exist in making such decisions, and how "poor" decisions can be and have been reached. Prior to the review, methods of collecting and organizing data are discussed.

3.1 METHODS

Using the four-category scheme of uncertainties presented in the introduction, we hypothesized 21 specific uncertainties thought to operate in evacuation decision making. We then identified the available reports and studies on evacuation. Table 2 lists these evacuations used to construct the data base and the reference numbers for the associated literature. We analyzed the content of these reports using the matrix in Appendix A. These data were reviewed and all cases of uncertainty were identified and each coded as to which category it represented, who experienced the uncertainty, and which stage of the decision was affected. A summary of the data included in this review is given in Appendix B.

After reviewing the data, we collapsed the original 21 categories into 19. These are presented in Table 3 along with a summary of the number of observations in each category.

Table 2. Evacuation included in the review

Hazard	Location	Event reference*
Dam failure	Baldwin Hill, CA	1
Flood	Rio Grande River	2
Dam failure	Port Jarvis, NY	3
Flood	Denver, CO	4, 5
Dam failure	Buffalo Creek, WV	6
Dam failure	Lawn Lake, CO	7
Flood	Big Thompson Canyon, CO	8
Flood	Louisville, KY	9
Flood	Washington State	11, 12
Flood	Tucson, AZ	14
Flood	Johnstown, PA	16
Tornado	Topeka, KS	17
Tornado	Worcester, MA	18
Tornado	Red River, AR	19
Volcano	Mt. St. Helens, WA	20, 21, 22, 24
Volcano	Kilauea, HI	23
Tsunami	Crescent City, CA	25
Tsunami	Hilo, HI	26
Nuclear accident	Three Mile Island, PA	27
Hurricane (Iwa)	Oahu, HI	28
Hurricane (Carla)	Gulf Coast	29, 30
Hurricane (Alicia)	Texas	31
Hurricane/flood	Gulf Coast and Eastern US	32
Chemical spill	Mississauga, Canada	33, 34, 35, 36
Chemical spill	Not available	34
Chemical fire	Taft, LA	37
Mud slide	Port Alice, Canada	38
Firework explosion	Houston, TX	41
Tsunami	Alaska	42
Hurricane	Gulf Coast, Eastern US	43
Tsunami	Crescent City, CA	44
Hurricane	Gulf Coast	46
Nuclear accident	Three Mile Island, PA	47
Hurricane	Coastal US	48
Flood	Big Thompson, CO	49
Hurricane	Coastal US	50
Hurricane	Texas	52
Various	Not specific	54
Hurricane	Gulf	55

*See Appendix B.

Table 3. Evacuation uncertainties

	Number of times uncertainties documented
Interpretation	
Recognition of event	21
Recognition of consequences/likelihood	16
Definition of magnitude	12
Self-definition of role	3
Recognition of relevant information	4
Definition of authority	13
Communications	
Who to notify	2
Ability to describe hazard	12
Physical ability to communicate	35
Conflicting information	10
Perceived impacts of decision	
Causing panic looting or other adverse responses	10
Loss of job/other personal consequences	4
Cost of evacuation or economic loss	5
Liability	4
Exogenous factors	
Time availability	9
Feasibility of evacuation	4
Prior experience	9
Planning	5
Outside pressures/expectations	7

Caution should be used in interpreting this data. First, it must be recognized that the studies and reports examined have not systematically sought to research or report on uncertainties. Thus, the lack of a documented case does not prove a particular uncertainty did not exist, nor that it has not affected decisions. Rather, it means only that it has not been recorded in this historical record. Second, the frequency of an observation does not reflect the magnitude of the uncertainty. On one hand it may mean that it occurs more frequently. On the other, it may mean it is simply more easily observed.

In the following sections, we review each uncertainty in the four major categories and discuss an example of each.

3.2 INTERPRETATION OF HAZARD, INFORMATION AND ROLES

The degree to which information about an impending hazardous event successfully works its way through from event detection to a prudent public evacuation decision is subject to the range of interpretations that the people who process that information make as they receive the information, interpret it, and pass it along to others. These interpretations, which are relevant to more than just how hazard information is interpreted, can facilitate the evacuation process if they are made soundly; or they can raise uncertainties in the system and give rise to bad decisions. In this section, we discuss interpretation uncertainties listed in Table 3.

3.2.1 Recognition of Event

The ability to recognize the presence of an impending hazardous event is determined by the degree to which people can observe an indicator associated with a potential threat and conclude from it that a threat exists. For example, observation of a particular cloud formation may mean rain for some, tornado threat to a few, and merely indicate a cloudy day to others. Variation exists in the ability of people to recognize a potential threat, and this variation exists among those who are "trained observers" as well as among general members of the public as well. Variation in the ability of people to recognize an impending hazardous event has constrained some evacuations in the past by consuming time thereby reducing the time available to the public in which to respond.

For example, in several recent dam failures, the private company responsible for managing the reservoir failed to understand that the dams were unsafe. Furthermore, when the dams were about to fail after periods of heavy flooding, the inability to link runoff conditions with dam failure precluded an early warning. This was characteristic of both the Buffalo Creek flood[1] and the Lawn Lake Dam disaster.[2]

3.2.2 Recognization of Hazard

Variation in ability to define the level of threat, once the event has been recognized, is a second uncertainty which has constrained effective and timely hazard recognition. Once the physical properties of an impending event are recognized -- for example, that a flood will occur or

a hurricane will strike -- uncertainties can exist in reference to what that event will mean for the people that will be affected. For example, an impending flood could affect a large part of town or only a small segment of town; or a hurricane could produce hazardous winds for 30 miles inland or only 3 miles. Uncertainty in the ability of people to recognize the extent of a public hazard associated with a recognized impending hazardous event has been the cause of over- and under-estimating the seriousness of impending emergencies. This uncertainty has led, in some cases, to less effective and poorly timed evacuation decisions.

Although the evacuation of 225,000 people in Mississauga, Canada, following a train derailment was effective, it was initially hampered by the inability to define the potentially hazardous materials on the train. At first, the manifest could not be located by local officials and when it was, it was unclear whether or not it was accurate.[3]

3.2.3 Definition of Magnitude

It is often difficult to forecast accurately the precise magnitude of hazard of an impending threatening event. For example, the precise windspeed of hurricanes when landfall occurs is difficult to foretell. Consequently, the inexactness of the sciences which seek to predict magnitude create uncertainty, on occasion, in terms of the advisability of evacuation. There are magnitudes of event for which evacuation is advisable, and others for which it is not.

Instances in which the magnitude of an impending event does not clearly indicate a need for evacuation create uncertainty and can lead to what appears to be wrong evacuation decisions in hindsight after the hazard impacts the area at risk. At the same time, this problem can also delay evacuations. The Rapid City flood,[4] for example, is a case in point. Heavy rains and rising water levels in the creek were both detected. However, the magnitude of the flood event was not accurately foreseen: the significant losses were associated with the breaking of a natural canyon dam not known to those estimating magnitude.

3.2.4 Self-definition of Role

People have sometimes experienced uncertainty in understanding, knowing, and effectively assuming the roles and obligations of participating in the communication process. This uncertainty has affected both those who initiate communication and those who receive it. People uncertain about their communication role do not always perform it. Consequently, role uncertainty by those who play key parts in the chain of communication in a warning system has slowed the evacuation by not conveying risk in a timely manner.

For example, the mining company responsible for creating the slag-heap reservoir on Buffalo Creek did not define their role as one of emergency responder. As a result, when the dam failed, no timely alert was given to public officials who could issue evacuation orders.[1]

3.2.5 Sorting of Relevant Information

Sorting of relevant information occurs when there is either too much or irrelevant information facing the decision-maker. It is then necessary to determine which pieces of information should be used to make a decision, and which should be ignored. For example, a local sheriff who must decide whether to activate an evacuation alarm system in the vicinity of a nuclear power plant might be given recommendations from three different organizations, and in addition he is given meteorological data, information on plant conditions, source terms, projected dose rates, etc. The sheriff may well be overwhelmed by the information. Some information may be excluded and the decision made on the basis of only part of the information. Another possibility is that the information is ignored and the decision is made on the basis of some exogenous factor. This uncertainty in how information is sorted may be reflected in the quality of the evacuation decision.

For example, when Mt. St. Helens became active, emergency response organizations were given "raw" data on seismicity and plume activity. In the course of trying to understand and use this data, they tended to neglect some responsibilities such as providing warnings to the public.[5]

3.2.6 Definition of Authority

Definition of authority is how various actors perceive the responsibility and power of other actors to make decisions. These definitions create uncertainties in several ways. First, if more than one person or

agency assumes a leadership role, conflicts could occur. Second, if definitions of authority are wrongly perceived, information may not reach the right people. Third, if no one takes charge because they perceive it as someone else's responsibility, decisions could be delayed or overlooked.

This was problematic among agencies and with private corporations preceding the large eruption at Mt. St. Helens.[5] In this situation, disagreement over evacuation authority arose between the U.S. Forest Service and a lumbering company. The Forest Service wanted to evacuate lands that were being harvested. The conflict led to a series of revisions in evacuation policies with compromises on both sides. Fortunately the eruption occurred on a Sunday when no logging was taking place.

3.3 COMMUNICATION PROBLEMS

Public evacuation advisements are usually the result of long chains of communication between different people, with varied jobs and roles, in different organizations. Consequently, a key to understanding the evacuation decision-making process is to view it as a series of communications between both people and organizations. This process of communication, involving people and organizations and ultimately the public, has been a general category of uncertainties that have surfaced in past evacuations to constrain the evacuation process. These uncertainties fall into four categories, and a description of each follows.

3.3.1 Who to Notify

Uncertainty over whom to communicate hazard information, either in reference to other organizations or the identification of particular persons in other organizations, has constrained the communication process in some past evacuations and, subsequently, delayed public evacuations. Sound hazard recognition and accurate determination of threat can be less than fully useful when that information is not communicated to all those who could carry that information through to other organizations and then the public. The dissemination of threat information to communities about to experience a potential disaster can be constrained if those who possess the threat information do not know what local agencies and which people within them to notify about the threat. For example, at Mt. St. Helens, the dissemination of a warning concerning ashfall levels and consequences has been attributed to the lack of pre-disaster interactions between state and local emergency organizations and the knowledge of whom to tell when the volcano erupted.

3.3.2 Ability to Describe Hazard

Those engaged in the provision of hazard information to others have created uncertainties because of how threat descriptions were worded. Non-scientists, for example, rarely share a common understanding of probabilities; vagueness in the specification of the area-at-risk can lead to increased uncertainties for those confused over which people to warn; and technical descriptions of physical processes associated with a hazard

may mean little to those interested in only simple definitions. The inability of some scientists and technicians to describe hazard in clear and simple ways has, sometimes, created uncertainties for those who must use that information to make decisions about public response and give public warnings. It has also created uncertainties in the sequential process of communication leading up to evacuation advisements.

For example at an explosion at a chemical plant in Taft, Louisiana, the evacuation of the surrounding population was delayed by an inability to communicate information about the explosion and potential consequences.[6] Company officials did not explain the accident in terms that local officials could readily use in making their decisions. Even when they recommended a five-mile evacuation, local officials did not understand why it should be that distance.

3.3.3 Physical Ability to Communicate

The physical ability to communicate notifications, alerts and warnings has been a source of uncertainty in some prior evacuations. Loss of the technical capacity to communicate can retard communications to both the public and to other organizations. Some reasons include, for example, the non-match of radio frequencies, the lack of dedicated phone lines when regular lines are overloaded, and the lack of back-up communications systems when planned or routine systems fail. A good example of a physical communication failure is provided by the 1977 Johnstown flood. The loss of the phone system hampered efforts of the Corps of

Engineers weather observer to determine rainfall and also for the NWS to subsequently alert local officials.[7]

3.3.4 Conflicting Information

Conflicting information is the presence of either data or recommendations which lead to different conclusions about whether to evacuate. In this situation, the decision-maker must decide which information is valid. For example, if a local official in charge of evacuation receives information from one source that a dam has overtopped and from another that it is sound, a decision to evacuate may be confused or delayed. If the erroneous information is acted upon, a bad decision may result.

This type of situation was encountered in the 1983 Hurricane Alicia. Local officials relied on official forecast information from the National Hurricane Center (NHC) and the Galveston National Weather Service Office. The local weather service was warning officials that the hurricane could take a northerly turn and hit Galveston. The NHC was concentrating on warning of a more southerly landfall. Galveston officials played down the potential of being affected and when the storm turned, it was too late to evacuate.[9]

3.4 PERCEIVED IMPACTS OF DECISIONS

Uncertainties also exist in the evacuation process because of a range of perceptions that people in decision-making roles hold regarding the potential negative impacts of making wrong decisions. Some of these

perceived impacts have no basis in reality and are part of a general myth-structure about public emergency response. Other perceived negative impacts are potentially real. Four types of impact perceptions were identified, and these follow.

3.4.1 Perceptions of Panic and Looting or Other Adverse Consequences

Evacuation decisions can be influenced by a decision-maker's perception of adverse public consequences of ordering an evacuation. Typical concerns may be that people will panic and be hurt or killed, or that homes will be looted while residents are away. While these situations may arise in some very rare circumstances, such beliefs are largely unfounded given previous experiences. Despite elaborate research evidence to the contrary, these beliefs still persist. In addition, decision-makers may also believe that a false warning may hinder future evacuation needs (the cry-wolf syndrome). There is, again, little research evidence that this is the case.

For example in Hurricane Carla, it was documented that the state government decided against a general evacuation order for fear of panic and unnecessary movement. Instead they let local governments make decisions.[9] In Hurricane Alicia several local governments, having evacuated unnecessarily for Hurricane Allen, decided not to evacuate for fear of being wrong again.[8]

3.4.2 Personal Consequences

Uncertainty has led to apprehensiveness in communicating and notifying other organizations and the public about an impending threat; often this results in downplaying the potential threat when it is communicated. Persons have feared personal negative consequences of transmitting risk information that may befall themselves with the non-occurrence of the hazard. Concern over personal consequences has centered on loss of reputation or image, loss of votes in a future election, and the like. For example, in a 1965 tsunami threat situation in Cresent City, California, local officials feared public sanctions if they called for another evacuation and no tsunami occurred.[10]

3.4.3 Perceptions of Cost or Losses from the Evacuation

Evacuation decision-makers can be influenced by their perceptions of the dollars costs or losses that may stem from an evacuation, particularly when it is precautionary. Cost may include transportation and sheltering of the public, as well as costs borne for emergency personnel. Losses can include revenues lost from employment or sales, or damages incurred from injury during evacuation, or the shutdown of productive sectors in an economy. A city, for example, which has exhausted its emergency funds for police overtime, may be reluctant to order an evacuation for which it cannot easily pay. For example, perceived economic losses played a significant role in determining evacuation zones at Mt. St. Helens. Evacuation boundaries were shifted in order to split

cost of manning roadblocks between two counties and to allow access to economic enterprises in the area.[5]

3.4.4 Perceptions of Liability

How agencies or actors within them define liability questions can also influence evacuation decisions. This can occur in several ways. First, and most likely, liability for public safety is a frequently raised issue for public agencies. The major concern is over responsibility for damages if a hazard occurs and actions are not taken to protect the public. This perception tends to cause officials to err on the side of caution in some situations. On the other hand, decision-makers may perceive liability for ordering an unneeded evacuation which leads to unnecessary costs and possible evacuation-associated damages.

Although the issue of liability as an influence on decision making is noted theoretically and is discussed in pre-emergency planning, it does not appear to be a major influence on actual decision making based on the data reviewed in this investigation.

3.5 EXOGENOUS INFLUENCES ON THE DECISION

Other uncertainties have surfaced to constrain good evacuation decisions and outcomes that are somewhat outside the domain of the evacuation decision-making process. These sources of uncertainty, here labeled as exogenous influences, are discussed in the sections which follow.

3.5.1 Time Availability

Time availability refers to the length of time between the detection of a hazard and the manifestation of impacts or effects. Judgments that a lengthy time exists may delay decisions. Judgments of short time may rush decisions. Furthermore, short response times may influence decisions to not evacuate for fear of people being exposed to damage while they are engaged in evacuating. Concern over adequate lead time to conduct an evacuation may lead to decisions to evacuate before sufficient information about the hazard may be collected. An example is a decision to evacuate a beach community or barrier island before the path or magnitude of a hurricane is known.

Such was the case in 1980 when Hurricane Allen threatened the Texas shoreline. Decisions to evacuate had to be made while the path was still subject to a wide prediction error. As a result, the NWS advised the evacuation of Galveston, only to have the storm veer to the south.

3.5.2 Evacuation Feasibility

Evacuation feasibility refers to the perceived success of an evacuation in protecting the public. Feasibility perceptions can be influenced by factors such as the severity of the hazard, geograpy, safety of evacuation routes and so forth. Misperceptions of feasibility could lead to poor decisions concerning evacuation or influence the timing of evacuation decisions. For example, the fear of a radioactive release during a fast-moving accident at a nuclear plant, in conjunction

with poor weather, could lead to an evacuation decision prior to development of plant conditions that would normally suggest that an evacuation is in order.

3.5.3. Experience

Prior experiences with other evacuations and emergencies can influence decision-maker judgments and raise uncertainties in the evacuation decision-making process. Occasionally, people can imagine that impending hazardous event will materialize in a way much like those which have already been experienced, even though this image may be inconsistent with current information about the impending event. On the other hand, the lack of experience with a particular hazard can, for some, raise uncertainty in imagining what an impending event may be like. Experience, and the uncertainties it can raise, can lead to either premature or tardy communications and evacuations.

This accident situation was experienced at Cresent City, California, during 1964. The warning of a potential tsunami which proved to be a false alarm played a role in delaying law enforcement officers' decisions to evacuate people in a subsequent warning situation.[10]

3.5.4 Prior Planning

The presence, absence or extent of in-place evacuation plans can greatly influence evacuation decisions. Experience shows that the lack of a plan can delay or confuse decisions to evacuate. Theoretically,

possession of an evacuation plan could increase the likelihood of having an evacuation merely because it has been planned for. Additionally, emergency plans which are too rigid and too inflexible can themselves frustrate timely emergency response and, subsequently, evacuations.

An example of the former is the accident at TMI. The lack of a plan definitely contributed to confusion over evacuation decisions.[11] Likewise, the absence of plans for special facilities like hospitals in the vicinity of TMI may have contributed to decisions to allow hospital employees to evacuate without consideration of the consequences.

3.5.5 Outside Pressures or Expectations

Evacuation decisions can be influenced by expectation or demands of persons outside the evacuation-decision environment. For example, a public official may perceive that, given a certain situation, an evacuation is expected by the public. In addition, a decision-maker may feel pressure from another level of government or some other agency when deciding whether or not to conduct an evacuation. At times the pressure may be counterproductive when the responsible official overacts to the pressure and follows the opposite course of action.

At TMI, the Governor's decision to recommend a selective evacuation was, in part, a response to outside demands and pressures to demonstrate control and leadership.[11]

During the approach of Hurricane Alicia, communication from the Governor to the Mayor of Galveston regarding evacuation may have played a role in the decision to not evacuate.[8] In this case the Mayor may have

4. CONCLUSIONS

4.1 GENERAL

A prime conclusion from this work is that uncertainties can affect all levels of government, including federal agencies, at virtually every decision point in the evacuation decision-making process (Table 4). This conclusion is not true for each specific evacuation; rather it is the case for evacuation experiences overall. Specific uncertainties for any given agency or level of government likely depend on both the hazard type and the evacuation context. Nevertheless, it appears that no agency at any level of government is immune from experiencing uncertainties in evacuation decision making.

Second, it is also the case that the private sector is subject to uncertainties at a variety of decision points, although they appear to be more restricted than for public agencies. The private sector, as evidenced by the historical record, seems more prone to uncertainties in detection and alert decision points than elsewhere.

Third, local and state governments frequently encounter or contribute to uncertainties in evacuation decisions. Given the structure and delegation of emergency powers in the federal, state and local governments will continue to bear the burden of responsibility for evacuation decisions.

Fourth, there are numerous examples in the historical record where potential grounds for liability were present due to uncertainties in evacuation decision making. If disaster losses occurred in these cases,

Table 4. Uncertainty observations characterized by organizational level and decision stage

Stage of decision model	Organizational level			
	Federal	State	Local	Private
Detection of hazard	7	0	4	7
Determination of threat	10	0	9	7
Decision to alert	3	0	0	2
Non-official notification	0	0	1	0
Alert	6	1	6	5
Interorganization notification	0	0	6	1
Official notification	1	0	11	1
Determination of threat	4	2	12	0
Decision to evacuate	1	2	54	5
Official evacuation	3	1	23	1

it might have been possible to document the factors that could have contributed to those damages in the context of poor evacuation decisions. Obviously, whether or not legal action, if pursued, would have been successful is unknown.

Finally, some of the uncertainties that have been identified in this research could be addressed in planning and they are somewhat likely, if addressed effectively, to be mitigated. For example, good emergency planning can define clearly who has what role in the evacuation decision-making process thereby reducing the potential for this as a source of uncertainty in a future evacuation. Other identified uncertainties likely cannot be readily mitigated; for example, hazard recognition is somewhat limited by the state-of-the-art in the sciences which allow the hazard to be monitored and detected. Uncertainty reduction on this front, therefore, must wait for future scientific discoveries relevant to upgrading event recognition. At the same time, most uncertainties likely fall somewhere in between these two polar extremes. Planning can, therefore, play some role in reducing uncertainties; although some uncertainties may always operate in the evacuation decision-making process.

4.2 IMPLICATIONS FOR PRICE-ANDERSON EXTENSION TO COVER PRECAUTIONARY EVACUATION

This research indicates that for evacuation in general, federal involvement with decision-making could leave the government potentially liable for contributions it makes to the decision process. For a nuclear power plant or other nuclear facilities emergency, it is less likely that

the federal government would be centrally involved in the decision to evacuate. Nevertheless, it is theoretically feasible given the roles that cognizant federal agencies have in an emergency, that a federal agency would contribute to a decision to evacuate.

Although this potential for liability exists, it is also important to note that the federal government has a long history of participation in evacuation decisions. Our research has documented occasions in which the performance of those agencies could have been seen as questionable. For example, it would be possible to associate the NWS with problems experienced in the 1972 Rapid City Flood. Litigation, despite the grounds, has rarely ensued. Thus, while a case for federal assumption of liability can be made on the basis of their involvement, it does not appear to be necessary given the previous history of their involvement with evacuations. This conclusion, however, rests more on the infrequency with which blame has been ascribed to federal agencies in the past, than it rests on a lack of uncertainties in decision making for evacuations. The latter exist, and they are numerous.

4.2.1 The Notion of "Precautionary" Evacuation

The concept of "precautionary" evacuation (evacuation that proves to be unnecessary) is largely an arbitrary one not based on sound analytical criteria. Evacuations are all ordered or advised with the expectation that a disaster will occur.

Often this is done under conditions of uncertainty. Uncertainty can arise in several ways. The major contribution is from the inherent

uncertainties in the hazard event. In addition, as we have documented, uncertainties result from problems in emergency response. Such problems can lead to "poor" evacuation decisions, but, nevertheless, ones based on protecting human safety.

The concept of precautionary evacuation is only relevent in the post-evacuation period when it can be based on a hindsight. If evacuation decision-makers were certain that a hazard would not harm people, it is most unlikely that an evacuation would be ordered.

Our review of evacuations indicate little value in labeling an evacuation as precautionary. In fact, most begin as precautions. Moreover, in many evacuations, people leave who may not have been harmed, and thus, many evacuations contain an element of precaution. It is often difficult and certainly futile to attempt to label part of an evacuation as precautionary and part as necessary.

Our recommendation is to abandon the notion of "precautionary" evacuation when considering the extension of the Price-Anderson Act. Although this may be a point with little administrative significance, it would make definition of an evacuation much more straightforward. With respect to Price-Anderson, the relevant distinctions appear to be evacuations with or without conditions of an extraordinary nuclear occurrence (ENO). An alternative is to redefine an ENO to include all events with an official evacuation. This would eliminate the need for trying to define and measure precautionary behavior.

REFERENCES

1. Erikson, K. T. (1976a), Everything in Its Path. New York: Simon and Schuster.

2. Graham, W. J. and C. A. Brown (1983), "The Lawn Lake Dam Failure: A Description of the Mjaor Flooding Events and an Evaluation of the Warning Process. Denver: Bureau of Land Reclamation.

3. Burton, I. (1981), The Mississauga Evacuation, Final Report. Toronto: Institute for Environmental Studies, University of Toronto.

4. Perry, R. W., M. K. Lindell, and M. R. Greene (1982a), "Crisis Communications: Ethnic Differentials in Interpreting and Acting on Disaster Warnings," Social Behavior and Personality 10 (No. 1): 97-104.

5. Sorensen, J. H. (1981), "Emergency Response to Mt. St. Helens' Eruption: March 20 to April 10, 1980," Working Paper 43. Boulder, Colorado: Boulder Institute of Behavioral Science, University of Colorado.

6. Quarantelli, E. L. (1983), "Evacuation Behavior: Case Study of the Taft, Louisiana Chemical Tank Explosion Incident." Columbus, Ohio: Disaster Research Center, The Ohio State University.

7. National Weather Service (1978), The Johnstown, PA Flood Washington, D.C.: U.S. Government Printing Office.

8. Savage, R., et al. (1984), "Hurricane Alicia, Galveston and Houston, Texas, August 17-18, 1983." Washington, D.C.: National Academy of Sciences.

9. Moore, H. E., F. L. Bates, M. V. Layman, and V. J. Parenton (1963), "Before the Wind: A Study of Response to Hurricane Carla," National Academy of Sciences/National Research Council Disaster Study #19. Washington: National Academy of Sciences.

10. Anderson, W. (1970c), "Tsunami Warning in Crescent City, California and Hilo, Hawaii," in The Great Alaska Earthquake of 1964: Human Ecology, Committee on the Alaska Earthquake of the National Research Council (ed.). Washington, D.C.: National Academy of Sciences.

11. The Accident at TMI: Report of the Emergency Preparedness and Response Task Force, Washington, D.C.: U.S. Government Printing Office.

reacted negatively against the state's position rather than make a decision independent of the state.

This section has provided a general overview of many uncertainties in evacuation decision making and has provided examples of each. The presence and absence of these factors or the response of a decision-maker to them help shape the potential liability of public officials and agencies for their decisions to evacuate. The list herein provided may not be exhaustive, and it is possible that other factors could also create uncertainties as well. Nevertheless it provides insights into the potentials for liability and allows us to draw some observations concerning Federal assumption of evacuation liabilities under the Price-Anderson Act.

APPENDIX A

MATRIX

Table A-1. Warning systems data matrix

	Process	1 Who	2 What	3 When	4 Where	5 How	6 Why	
							a Constraints	b Incentives
A	Detection	A1	A2	A3	A4	A5	A6a	A6b
B	Measurement	B1	B2	B3	B4	B5	B6a	B6b
C	Collation	C1	C2	C3	C4	C5	C6a	C6b
D	Interpretation	D1	D2	D3	D4	D5	D6a	D6b
E	Decision to warn	E1	E2	E3	E4	E5	E6a	E6b
F	Message content	F1	F2	F3	F4	F5	F6a	F6b
G	Dissemination	G1	G2	G3	G4	G5	G6a	G6b
H	Warning	H1	H2	H3	H4	H5	H6a	H6b

APPENDIX B

DATA

DATA

The data collected is summarized in code form in Table B-1. This table lists all key decisions and communication links on one axis and uncertainties on the second axis. Codings in the matrix are an alpha and numeric entry with the letter representing the organization and the number of the study from which the data was derived. Organizational codes are found in Table B-2 and the study codes are found in the following reference list. For example, a code of O-15 at the intersection of the "decision to evacuate" and "physical ability to communicate" means that documentation exists in a study by the National Weather Service on the Rapid City Flood that several agencies had difficulties in physically communicating information which disrupted the decision to order an evacuation. In this particular case, the lack of phone service delayed communications between the local agencies who were trying to decide on issuing an evacuation advisement.

Table B-1. Uncertainties

	Detection of hazard	Determination of threat	Decision to alert	Non-official notification	Alert	Inter-organizational notification	Official Notification	Determination of threat	Decision to evacuate	Official evacuation warning
Recognization of event	A-4; A-5; A-8; B-1; B-6; B-7; E-8; E-13; K-1; O-5; O-8	B-7; E-13; E-28; E-30; O-36						E-7; K-37; E-16	A-18; K-25; O-1; O-43	
Recognizing the hazardous consequences/ likelihood	B-11b; E-8	A-7; E-30; K-33; O-7; O-9; O-33; O-34; O-40	C-6				M-2; O-7	M-37; O-9; O-13	K-36	L-13
Definition of magnitude		B-37; E-13; E-15; E-24			K-12; R-30			O-8	M-31; O-23; O-34	E-24; O-43
Self-definition of role					B-6; B-11b; E-18					
Ability to ascertain relevant information out of irrelevant information		K-36						G-24; M-4	O-3	
Definition of authority	A-4								B-24; C-3; C-37; K-30; M-54; O-7; O-42	E-47; M-30; K-1; O-5; O-7
Who to notify				O-2				O-42		O-54
Ability to describe hazard		A-17; B-34	E-30		E-13; L-34			E-15; E-24; O-34	E-15; G-25; K-25; M-37	
Physical ability to communicate	E-13; E-15; E-32	E-13; E-16			A-7; E-16; E-32; E-34; G-28; K-32; K-36	K-36; L-38; P-38	E-32; K-1; L-4; L-12; L-34; M-1; M-4; R-7	P-16	M-4; O-15	A-7; E-7; K-1; K-8; L-28; L-34; O-12; O-15; O-37; O-42

Table B-1. (continued)

	Detection of hazard	Determination of threat	Decision to alert	Non-official notification	Alert	Inter-organizational notification	Official Notification	Determination of threat	Decision to evacuate	Official evacuation warning
Conflicting information			E-31	O-37			K-4	I-13; O-54	G-25; M-44; O-3; O-34; O-54	
Causing looting or panic			A-38; E-31				O-7		K-29; M-31; M-44; M-46; O-3; O-53; O-54	
Loss of job or other personal consequences									K-25; K-29; M-29; O-54	
Cost of evacuation		E-20							L-1; O-24; O-54; P-1	
Liability for evacuation									E-24; O-48; O-54; O-55	
Time available		R-17				K-12; O-42			K-25; L-45; M-46; O-54	K-1; K-4; K-11; K-12; O-7; O-49; O-54
Feasibility of evacuation					R-37		K-7		O-7; O-50; O-52	
Previous experience	O-41	M-4; E-28						M-4; M-5	K-25; M-31; O-20	O-43
Planning	E-24				E-16	B-11			K-25; O-7	
Pressure and expectation of outside groups		C-23			E-31	O-34			C-20; L-45; O-50; O-54	

Table B-2. Classification of organizational codes in Table B-1

Private

- Individual/citizens (A)
- Organization with Hazard Management Responsibility (B)
  (e.g., chemical compounds)
- Private Disaster Response Organization (Q)
- Other (C)

Federal Government

- Non-regulatory Agency (E)

State Government

- Elected Office (H)
- Law Enforcement (F)
- Emergency Services (G)
- Technical (I)

Local Government

- Elected Office (M)
- Law Enforcement (K)
- Emergency Service (L)
- Fire (P)
- Technical (N)
- Miscellaneous or Multiple Roles (10)
  (May include other system level organizations)
- Media (R)

REFERENCES

1. Anderson, W. (1964), "The Baldwin Hill, California Dam Disaster," Research Note No. 5. Columbus, Ohio: Disaster Research Center, Ohio State University (cited in Quarantelli, 1980).

2. Clifford, R. A. (1956), "The Rio Grande Flood: A Comparative Study of Border Communities," National Research Disaster Study #17. Washington, D.C.: National Academy of Sciences.

3. Danzig, E. R., P. W. Thayer and L. R. Galanter (1958), "The Effects of a Threatening Rumor on a Disaster-Stricken Community," Disaster Study #10. Disaster Research Group. Washington: National Academy of Sciences.

4. Drabek, T. E. (1969), "Social Processes in Disaster: Family Evacuation," Social Problems 16 (Winter): 336-349.

5. Drabek, T. E. and J. S. Stephenson III (1971), "When Disaster Strikes," Journal of Applied Social Psychology 1 (No. 2): 187-203.

6. Erikson, K. T. (1976a), Everything in Its Path. New York: Simon and Schuster.

7. Graham, W. J. and C. A. Brown (1983), "The Lawn Lake Dam Failure: A Description of the Major Flooding Events and an Evaluation of the Warning Process. Denver: Bureau of Land Reclamation.

8. Gruntfest, E. (1977), "What People Did During the Big Thompson Flood," Working Paper 32. Boulder: Institute of Behavioral Science, University of Colorado.

9. Kutak, R. I. (1938), "The Sociology of Crises: The Louisville Flood of 1937," Social Forces 17: 66-72.

10. Mileti, D. S. and E. M. Beck (1975), "Communication in Crisis: Explaining Evacuation Symbolically," Communication Research 2 (January): 24-49.

11. Perry, R. W., M. K. Lindell and M. R. Greene (1981), Evacuation Planning in Emergency Management. Lexington, Massachusetts and Toronto: Lexington Books.

12. Perry, R. W., M. K. Lindell and M. R. Greene (1982a), "Crisis Communications: Ethnic Differentials in Interpreting and Acting on Disaster Warnings," Social Behavior and Personality 10 (No. 1): 97-104.

13. National Academy of Sciences (1983), The Tucson Flood, Washington, D.C.: National Academy of Sciences Press.

14. National Academy of Sciences (1982), Southern California Floods and Mudflows, Washington, D.C.: National Academy of Sciences Press.

15. National Weather Service (1973), The Blackhills Flood, Washington, D.C.: U.S. Government Printing Office.

16. National Weather Service (1978), The Johnstown, PA Flood, Washington, D.C.: U.S. Government Printing Office.

17. National Weather Service (1980), The Topeka, KA Tornado, Washington, D.C.: U.S. Government Printing Office.

18. Wallace, A. F. (1956), "Tornado in Worcester," National Academy of Sciences, National Research Council Disaster Study #3. Washington, D.C.: National Academy of Sciences.

19. National Weather Service (1960), The Red River Tornadoes, Washington, D.C.: U.S. Government Printing Office.

20. Greene, M., R. Perry and M. Lindell (1981), "The March 1980 Eruptions of Mt. St. Helens: Citizen Perceptions of Volcano Threat," Disasters 5 (No. 1): 49-66.

21. Perry, R. W. and M. R. Greene (1983), Citizens Response to Volcanic Eruptions: The Case of Mount St. Helens, New York, New York: Irvingtgon Publishers, Inc.

22. Perry, R. W., M. Lindell and M. R. Greene (1982b), "Threat Perception and Public Response to Volcano Hazard," The Journal of Social Psychology 116: 199-204.

23. Sorensen, J. H. and P. J. Gersmehl (1980), "Volcanic Hazard Warning System: Persistence and Transferability," Environmental Management 4 (March): 125-136.

24. Sorensen, J. H. (1981), "Emergency Response to Mt. St. Helens' Eruption: March 20 to April 10, 1980," Working Paper 43. Boulder, Colorado: Boulder Institute of Behavioral Science, University of Colorado.

25. Anderson, W. (1970c), "Tsunami Warning in Crescent City, California and Hilo, Hawaii," in The Great Alaska Earthquake of 1964: Human Ecology, Committee on the Alaska Earthquake of the National Research Council (ed.), Washington, D.C.: National Academy of Sciences.

26. Bonk, W., R. Lachman and M. Tatsuoka (1960), "A Report of Human Behavior During the Tsunami of May 23, 1960." Hilo, Hawaii: Hawaiian Academy of Science.

27. The Accident at TMI: Report of the Emergency Preparedness and Response Task Force, Washington, D.C.: U.S. Government Printing Office.

28. Chiu, A. et al. (1983), "Hurricane Iwa, Hawaii, November 23, 1982." Washington, D.C.: National Academy of Sciences.

29. Moore, H. E., F. L. Bates, M. V. Layman and V. J. Parenton (1963), "Before the Wind: A Study of Response to Hurricane Carla," National Academy of Sciences, National Research Council Disaster Study #19, Washington: National Academy of Sciences.

30. Moore, H. E., with the collaboration of F. L. Bates, J. P. Alson, M. M. Fuller, M. V. Layman, D. L. Mischer and M. M. White (1964), And the Winds Blew. Austin, Texas: The Hogg Foundation for Mental Health, University of Texas.

31. Savage, R., et al. (1984), "Hurricane Alicia, Galveston and Houston, Texas, August 17-18, 1983." Washington, D.C.: National Academy of Sciences.

32. National Weather Service (1973), Hurricane Agnes, Washington, D.C.: U.S. Government Printing Office.

33. Burton, I. (1981), The Mississauga Evacuation, Final Report. Toronto: Institute of Environmental Studies, University of Toronto.

34. Gray, J. (1981), "Three Case Studies of Organized Responses to Chemical Disaster," Misc. Report No. 29. Columbus, Ohio: Disaster Research Center, Ohio State University.

35. Liverman, D. and J. Wilson (1981), "The Mississauga Train Derailment and Evacuation, 10-16 November 1979," The Canadian Geographer 25: 365-375.

36. Scanlon, T. J., with M. Padgham and Whitehorse Star (1980), The Peel Regional Police Force and the Mississauga Evacuation. Ottawa, Ontario: Canadian Police College.

37. Quarantelli, E. L. (1983), "Evacuation Behavior: Case Study of the Taft, Louisiana Chemical Tank Explosion Incident." Columbus, Ohio: Disaster Research Center, the Ohio State University.

38. Scanlon, T. J., J. Jefferson and D. Sproat (1976), "The Port Alice Slide," (EPC Field Report 76/1). Ottawa, Ontario, Canada: Emergency Planning Canada.

39. Mack, R. W. and G. W. Baker (1961), The Occasion Instant, National Academy of Sciences, National Research Council Disaster Study #15. Washington, D.C.: National Academy of Sciences.

40. Diggory, J. C. (1956), "Some Consequences of Proximity to a Disease Threat," Sociometry 19 (March): 47-53.

41. Killian, L. M. (1956), "A Study of Response to the Houston, Texas Fireworks Explosion." National Academy of Sciences, National Research Council Disaster Study 2 . Washington, D.C.: National Academy of Sciences.

42. Haas, J. Eugene and Patricia Trainer (1973), "Effectiveness of the Tsunami Warning System in Selected Coastal Towns in Alaska." In Proceedings of the Fifth World Conference on Earthquake Engineering held in Rome.

43. Baker, Earl J. (1979), "Predicting Response to Hurricane Warnings: A Reanalysis of Data from Four Studies," Mass Emergencies 4: 9-24.

44. Yutzy, Daniel (1964), "Contingencies Affecting the Issuing of Public Disaster Warnings at Crescent City, California," Disaster Research Center Research Note #4.

45. Wilkerson, K. and P. Ross (1970), Citizen Response to Warnings of Camille. College Station, Mississippi: Mississippi State University.

46. Louisiana Department of Public Safety (1984), Southeast Louisiana Hurricane Study Evacuation Behavioral Survey, Final Report, July 1984, Office of Emergency Preparedness, Department of Public Safety, Baton Rouge, Louisiana.

47. National Academy of Public Administration (1980), Major Alternatives for Government Policies, Organizational Structures, and Actions in Civilian Nuclear Reactor Emergency Management in the U.S.," NUREG/CR-1225.

48. Wendell, Mitchell (1980), "Legal Aspects of Flood Warning and Evacuation," in E. J. Baker (ed.), Hurricanes and Coastal Storms, Florida Sea Grant College Report #33,

49. Gruntfest, Eve (1978), "Big Thompson Flood Exposes Need for Better Flood Reaction System to Save Lives," Civil Engineering 48.

50. Ruch, Carlton and Larry b. Christenson (1981), Hurricane Message Enhancement. Texas A & M University, Sea Grant College Program.

51. National Academy of Sciences (1978), "A Program of Studies on the Socio Economic Effects of Earthquake Predictors." Washington, D.C.: National Research Council, National Academy of Sciences.

52. Urbanik, Thomas (1978), Texas Hurricane Evacuation Study. Texas Transportation Institute, Texas A&M University (Sept.).

53. National Academy of Sciences (1975), Earthquake Prediction and Public Policy. Washington, D.C.: National Academy of Sciences.

54. Quarantelli, E. (1980), Evacuation Behavior and Problems, Columbus: Disaster Research Center, Ohio State University.

55. Windham, G. E. Posey, P. Ross and B. Spenser (1977). Reaction to Storm Threat During Hurricane Eloise. College Station, Mississippi: Mississippi State University.

INTERNAL DISTRIBUTION

1. M. V. Adler
2. B. J. Bjornstad
3. M. A. Brown
4. R. A. Cantor
5. S. A. Carnes
6. R. M. Davis
7. M. L. Emrich
8. W. Fulkerson
9. K. S. Gant
10. E. L. Hillsman
11. C. R. Kerley
12. V. C. Mei
13. D. M. Neal
14. B. E. Peterson
15. S. Rayner
16. L. W. Rickert
17. R. E. Saylor
18. M. Schweitzer
19. R. B. Shelton
20. E. J. Soderstrom
21-30. J. H. Sorensen
31. F. Southworth
32. T. J. Wilbanks
33. H. E. Zittel
34-35. Central Research Library
36-37. Document Reference Section
38-40. Laboratory Records
41. Laboratory Records Department - RC
42. ORNL Patent Office

EXTERNAL DISTRIBUTION

43. Office of the Assistant Manager for Energy Research and Development, DOE-ORO
44. William Bogard, Department of Sociology, University of Colorado, Ft. Collins, CO 80521
45. Robert H. Bonczek, Associate Professor of Management, Krannert Graduate School of Management, Purdue University, West Lafayette, IN 47907
46. S. Malcolm Gillis, Professor, Public Policy and Economics, Duke University, 4875 Duke Station, Durham, NC 27706
47. Fritz R. Kalhammer, Vice President, Electric Power Research Institute, P. O. Box 10412, Palo Alto, CA 94302
48. Roger E. Kasperson, Professor of Government and Geography, Graduate School of Geography, Clark University, Worcester, MA 01610
49. Martin Lessen, Consulting Engineer. 12 Country Club Drive, Rochester, NY 14618
50-54. Dennis Mileti, Department of Sociology, University of Colorado, Ft. Collins, CO 80521
55. William F. Savage (NE-43), Room E459, U.S. Department of Energy, Washington, DC 20545
56. William F. Wolff, Office of Nuclear Safety, EH-132, U.S. Department of Energy, Washington, DC 20545
57-83. Technical Information Center, DOE-ORO, Building 1916 T-1