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Evacuation: An Assessment of Planning and Research

John H. Sorensen
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Dennis S. Mileti

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ENERGY DIVISION

EVACUATION: AN ASSESSMENT OF PLANNING AND RESEARCH

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EXECUTIVE SUMMARY

EVACUATION: AN ASSESSMENT OF PLANNING AND RESEARCH

The purpose of this research was to assess issues and criticism of evacuation planning for all hazards under an integrated emergency management concept, and to review research that addresses those issues. The work identifies gaps in knowledge about evacuation planning issues and the research that could address these gaps.

In the course of this research, over 300 documents were reviewed and abstracted, and key findings were summarized. Issues were identified by review of hearings, litigations, critiques, and discussions with planners and experts. A comparison of the research findings with the issues leads to the conclusions presented in this executive summary.

ES 1. PROGRESS IN EVACUATION PLANNING: 1975-1985

Over the past decade, evacuation planning has become more sophisticated and advanced. Progress has been made in at least four major ways. First, evacuation planning for some hazards has integrated physical risk studies with quantitative evacuation traffic modeling and behavioral research to produce comprehensive planning guidance. The best examples of this approach are found in hurricane evacuation planning and nuclear power plant evacuation planning. For the former, extensive modeling of hurricane storm surge defines the maximum levels of water inundation. Vulnerability studies identify populations at risk, and behavioral studies are used to estimate evacuation departures and destination. Combined with a quantitative evacuation time estimate, local emergency planners know when they must make an evacuation decision and which areas to evacuate. This type of approach is less well developed for other hazards, although FEMA is moving in the direction of initiating similar programs for some other hazard types. Second, the adoption of an integrated or generic emergency management approach has and will further bolster the expediency of evacuation planning. Given the integrated scientific approach being pursued, integrated planning will eliminate many overlapping planning tasks. Furthermore, it will encourage more flexible emergency evacuation capabilities that will apply to most conceivable contingencies.

Third, over the past 10 years, most aspects of evacuation logistics have been defined and researched and, as a result, are well understood. Withstanding the issues raised in the subsequent section, the knowledge of how to move small or moderately large numbers of people is fairly well developed. This does not mean this knowledge has been implemented or adopted in all evacuation plans, or that some hazard-specific uncertainties have been eliminated. Overall, however, we know the resource

requirements needed to evacuate most populations from threatened areas in a reasonable length of time.

Finally, there are indications that the local implementation of evacuation procedures has improved. Each year thousands of people are successfully evacuated from floods and hazardous-material accidents. Evacuation rates from high risk coastal areas preceding hurricanes are very high, and deaths from hurricane surge have been significantly reduced. Many specific success stories could be cited.

Some issues concerning evacuation planning still, however, remain unresolved. The fact is that people who could have evacuated to safety continue to die in disasters. The next section defines and discusses these issues.

ES 2. UNRESOLVED ISSUES IN EVACUATION PLANNING

Our research has identified ten major issues in evacuation planning that cut across hazards. These are issues that can be completely or partially resolved through additional research. Additional hazard-specific issues also exist and are addressed in the accompanying report. Each issue is now discussed and general research needs are identified.

ES 2.1 PLANNING FOR LARGE SCALE EVACUATIONS

Several issues regarding the planning needs for and feasibility of evacuating large urban areas are still unresolved. Large-scale evacuation concepts have been primarily derived from the now abandoned crisis relocation planning and from hurricane evacuation planning. Under the integrated planning concept large-scale evacuations are applicable for many hazardous situations in heavily populated areas. For example, an earthquake prediction could lead to large population movements, as could a nuclear transport accident or a terrorist-placed nuclear weapon.

Uncertainty stems from questions regarding extrapolation of the well-defined logistics of evacuation of small populations to massive ones. For example the logistics of reverse traffic flow after a sporting event are understood; however, it is unclear whether they could apply to evacuation routes out of Dade County, Florida, following a hurricane evacuation decision. The Federal Emergency Management Agency (FEMA) has made significant progress toward providing planning guidance on large-scale evacuation although some of the principles remain untested and perhaps are untestable.

Second, under an integrated approach, it is unclear what special planning elements for large-scale evacuation will be adopted by large cities. Furthermore, there is a need to ensure consistency in planning guidance coming from FEMA regarding large-scale evacuation. Conceptually

evacuating Miami for a hurricane is not greatly different than evacuation for other possible causes.

Finally, we are of the opinion that large-scale evacuation planning may have implementation problems; however, these problems do not warrant abandonment of planning or even plan implementation. Emergency management is not a zero-risk process; it is a design to prevent loss of life and property. Continued efforts at refining abilities to move large populations and estimating the effectiveness of evacuations are warranted.

ES 2.2 SPECIAL EVACUATION PLANNING NEEDS FOR FAST MOVING EVENTS

Evacuation has routinely been cast as a solution to lost lives and moveable property when enough time exists for its successful implementation. Available time between the detection of a disaster's impending impact and its striking an endangered population, however, can be and has been short. Little is known about the special planning needs for fast-moving events that could help implement fast evacuations. Research to develop and integrate needed knowledge on special evacuation planning needs for fast moving events cuts across a range of physical, technological, and social sciences. For example, we lack physical studies of risk for some hazards on which planning must be based. Additionally, it is not known what special emergency information requirements are needed for a population that must move quickly, or if even special information schemes could encourage quick response. Hazard-specific studies are in order to determine differences in quick response evacuations and to identify alternative fast evacuation strategies; for example, climbing canyon cliffs to escape mountain flash floods. Finally, technical and physical knowledge about risk must be integrated with social science knowledge about quick response to provide a basis for drafting special planning needs and technical assistance for fast-moving events.

ES 2.3 EVACUATION PLANNING FOR CONCURRENT HAZARDOUS EVENTS

Integrated emergency management cannot ignore concurrent hazards that can strike communities at the same time. Recent history catalogues many examples. The 1971 San Fernando Earthquake, for example, saw the need for a large evacuation of people at risk because of a potential dam failure. Additionally, a severe storm in California recently was the cause of a spill of hazardous material and precipitated an evacuation <u>during</u> the storm. Insufficient knowledge exists to catalogue and identify unique problems created by concurrent hazardous events on which to mount sound preparedness plans. Comprehensive investigations of concurrent hazards are in order, and these should carefully distinguish between two classes of concurrent events. First, concurrent hazards can be linked; one event may cause another, and these are not uncommon. These may occur simultaneously, or with one subsequent to the other. Second, concurrent hazards may be independent of each other, and these are uncommon with, more often than not, low statistical odds. A basis must be developed to distinguish between these types, identify which concurrent hazards are

realistically planned for, and identify unique planning problems for concurrent hazards and how to take them into account in the general planning process.

ES 2.4 HUMAN BEHAVIOR IN EVACUATIONS

The key to a successful evacuation is getting the people who are at risk to move to an area that is safe. Consequently, the bottom-line in evacuations is understanding, planning on the basis of, and implementing the lessons available from the social sciences about public response to evacuation advisements, orders, and public risk information in emergencies. Knowledge about public evacuation behavior is broad; however, it is the result of a piecemeal effort that pulled together the findings of divergent pieces of research involving varied hazards and using somewhat different research designs, methods, approaches, and models. Consequently, we have no systematic evidence to suggest, for example, that differences in hazards make a difference in public response on which to fine-tune evacuation planning. What is needed is a cross-hazard investigation of public evacuation behavior using state-of-the-art research designs, methods, and theoretical models to reveal the commonalities and differences in public evacuation behavior. Such a cross-hazards investigation would facilitate more accurate evacuation planning.

ES 2.5 ACCURACY OF EVACUATION TIME ESTIMATES

Currently, evacuation time estimates are derived from a number of different models and modeling procedures. These estimates are used to meet regulatory requirements, to prepare plans, to understand the timing of evacuation decisions, and to determine the effectiveness of evacuation as a protective action strategy. Evacuation time models' accuracy has been challenged in hearings regarding nuclear power plant licensing, in critiques of large-scale evacuation planning, and to a lessor degree in development of hurricane response plans. The major issues regarding these models are threefold.

First, different models are used for different hazards and for different geographical regions. These differences are not based on special geographical features or on different hazard characteristics, but on different researchers or contractors. A more systematic and coordinated approach under an integrated framework would be desirable.

Second, the assumptions made by various models and the variables they include and exclude are largely unarticulated across model type. It would be useful to understand the possible biases and sources of potential errors created by model assumption and structure.

Third, current models lack validity, that is, a comparison of their predictions with real-life experience. To our knowledge, no attempt has been made to compare model results with actual times derived from an

emergency evacuation. As a result, the errors in the evacuation time estimates are largely unknown.

ES 2.6 REENTRY AFTER EVACUATION

Evacuation is too often viewed as a singular act--movement of people out of an endangered area to one of safety. It is actually a process that includes other decisions and moves. Reentry of the evacuated population into the evacuated area is an issue faced in every evacuation; there are few permanent evacuations. Reentry is not a straightforward affair, and it can be riddled with problems and risks. For example, the recent evacuation of communities in the Carolinas because of Hurricane Diane saw some towns reinhabited prior to landfall of the hurricane. The Three Mile Island evacuation was somewhat confused over when reentry would be appropriate (e.g., when risk was over). The reentry of Livingston, Louisiana, after the Illinois Central Gulf Railroad derailment and hazardous waste fires was on-again/off-again for several weeks. The gaps in plans over reentry are obvious and great, as are behavioral studies to investigate issues and problems of reentry on which a planning effort could be based. It is not clear why or how plans should address reentry, nor how or what guidance should be given to those who develop evacuation plans. Integrated emergency management must address reentry systematically; to continue to slight this issue would be to ignore how best to keep evacuees who are safe from subjecting themselves to the risk they have just avoided.

ES 2.7 SPECIAL POPULATIONS PLANNING NEEDS

Special populations are groups of people whose needs may not be met by general evacuation planning. These populations may be concentrated in prisons, hospitals, schools, nursing homes, and other institutional populations, or dispersed such as nonambulatory, deaf, mentally retarded, or foreigners. Some populations can possess characteristics of both, for example, tourists. Some research has been conducted on the problems of evacuating special populations, and more is currently underway. This knowledge, however, is somewhat dispersed and may not be readily accessible to evacuation planners--it should be identified and consolidated. In addition, ways in which it can be presented and adopted into evacuation plans should be explored. Existing research may not address all logistical issues of moving special populations. Practical planning guides for evacuation resource need and plan implementation would be beneficial to local planners.

ES 2.8 LIABILITY FOR EVACUATION

There is widespread concern among emergency managers about their liabilities when ordering of an evacuation. Their concerns include liability for damages incurred if no disaster occurs, liability for damages if no evacuation is ordered, or liability for damages if the

evacuation order is late or covers an inappropriate area. The problem associated with such concerns is not who eventually would win litigation of such claims but rather if these concerns might interfere with making sound evacuation decisions based on technical criteria and experience.

If liability or perceptions of liability act as a constraint to evacuation or affect evacuation decisions, then it would be desirable to take actions to remove those constraints. This would involve improving the understanding about how emergency managers make evacuation decisions in general and, specifically, how liability affects decisions. Second, this would involve additional work on the grounds for liability and actions that could remove liability without threatening the rights of the public.

ES 2.9 UNCERTAINTIES IN DECISION-MAKING

Deciding when and where to evacuate in the face of an impending disaster is a thorny issue for most hazard situations. Usually there are some uncertainties involved. For nuclear accidents, source terms may be incorrectly estimated and winds may shift. For hurricanes, the 24-hour forecast error is plus or minus 100-125 miles. Such uncertainties create several planning or decision dilemmas for planners and officials.

First, evacuation zones are predetermined; however, it is unclear whether or not worst-case assumptions should be used in delineating evacuation zones. What constitutes a reasonable planning basis needs clearer definition.

Second, as pointed out under liability, we have a poor understanding about how local officials make evacuation decisions. Improving that understanding would help to provide better guidance for decision-making.

Third, prescriptive decision tools are being developed to aid decision-making. It is not clear how these tools will be used, whether they will result in better decisions or even if they will be adopted. An assessment of prescriptive decision tools, including articulation of their biases and limits and investigation of their use, seems warranted. Furthermore, if more tools are developed, across-hazard differences in tool applicability and tool flexibility for multi-hazard use may require investigation.

ES 2.10 ADOPTION OF INTEGRATED EMERGENCY MANAGEMENT SYSTEMS

During the past decade, our knowledge about evacuation principles has grown, along with out ability to plan successfully for the effective implementation of evacuation plans. At the same time, this information has been widely disseminated and shared with state and local users, as well as members of the private sector. The current state of these users' adoption of this evacuation planning information is not fully known. It is not known, for example, the degree to which the cross-hazard emergency

management approach has truly replaced hazard-specific approaches in local and state entities. More importantly, if the approach has had a slow start in some places, the constraints to its adoption have not been clearly identified so that efforts could be made to remove them. Additionally, existing knowledge may not be fully taken advantage of on all fronts where it could be used. For example, we know what and how emergency public information and warnings should be presented to facilitate a public evacuation, but we do not know the extent of full adoption in local evacuation plans. Work must be done to determine how to better assist local and state entities in implementing state-of-the-art evacuation planning and its full adoption in local evacuation plans.

ES 3.0 IMPROVING EXISTING PLANNING USING CURRENT KNOWLEDGE

Several steps can be taken to improve existing evacuation planning, independent of the development of new knowledge. The most significant is the adoption of a systematic method for developing a plan such as the process described in the hurricane program. This involves identifying the nature of threats and their geographical distribution, estimating the time available from detection of the hazard until the point where evacuation is not feasible, calculating how long it will take to evacuate, and developing guidelines to implement an evacuation based on these estimates and other relevant data. The full details of this process are outlined in Chapter Two. This, however, can be implemented as a relatively simple procedure or fairly complex one depending on the seriousness of the threat and available resources or expertise. Even if it is a simple effort, the benefits still can be significant because planning will have led officials to a better understanding of the decision-making process.

The second step to improve the effectiveness of evacuation planning is to advance the application of existing knowledge of state-of-the-art hazard warning and emergency communication systems. Poor or problematic evacuations are often due to the failure to notify the public at risk or to provide good information. Much is known at the present time about how to design good warning systems. This knowledge has not been systematically applied in the development of plans and operating procedures. Better warnings have had a dramatic impact on reducing fatalities from hurricanes; further improvements are still possible, and for a number of other hazards, much could be done to increase citizen compliance with protective action recommendations, including evacuation.

Third, evacuation plans can be improved to better meet the needs of special or institutional populations. Although the technical basis for evacuating special populations still needs improvement, identifying the means and resources needed to evacuate institutions in high risk areas is certainly feasible. This is often done after problems or near misses are experienced. In addition, developing mechanisms for more effective communication with minority or other populations who are reluctant to evacuate is also possible but usually ignored. Improvements can be made but are often not politically salient.

Finally, developing more effective organizations to implement evacuation plans and make evacuation decisions is feasible at all levels of government. This can be done with little or no expenditure of additional resources in many cases but may involve redirecting planning efforts. This will involve, however, the development of new planning guidance and training materials that will incorporate existing knowledge of organizational effectiveness in planning and emergency response.

EVACUATION: AN ASSESSMENT OF PLANNING AND RESEARCH

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ABSTRACT

The purpose of this research was to assess issues and criticisms of evacuation planning for all hazards under an integrated emergency management concept and to review research that addresses those issues. The work identifies gaps in knowledge about evacuation planning issues and research that can address these gaps.

In the course of this research, over 300 documents were reviewed and abstracted, and key findings were summarized. Issues were identified by review of hearings, litigations, critiques, and discussions with planners and experts. A comparison of the research findings with the issues lead to the following conclusions.

Over the past decade, evacuation planning has become more sophisticated and advanced. Progress has been made in at least four major ways. First, evacuation planning for some hazards has integrated physical risk studies with quantitative evacuation traffic modeling and behavioral research to produce comprehensive planning guidance. Second, the adoption of an integrated or generic emergency management approach has bolstered and will further bolster the expediency of evacuation planning. Third, over the past ten years, most aspects of evacuation logistics have been defined and researched and, as a result, are well understood. Finally, there are indications that the local implementation of evacuation procedures has improved.

Some issues concerning evacuation planning still, however, remain unresolved. The fact is that people who could have evacuated to safety continue to die in disasters. Our research has identified ten major issues in evacuation planning that cut across hazards. First, planning for large-scale evacuations requires improvement. Second, a better understanding of special evacuation planning needs for fast-moving events is needed. Third, evacuation planning for concurrent hazardous events is lacking. Fourth, a better understanding of human behavior in evacuations is desirable. Fifth, the accuracy of evacuation time estimates should be established. Sixth, guidelines on reentry after an evacuation should be improved. Seventh, special populations planning requires further investigation. Eighth, liability for evacuation decisions should be resolved. Ninth, uncertainties and problems in evacuation decision-making need greater attention. Finally, adoption and implementation of integrated evacuation plans should be investigated.

1. EVACUATION AS A PLANNING PROBLEM

Evacuation of a group of people due to a threat or impending disaster is almost a daily happening somewhere in the United States. At some populated location a rail tank car leaked ammonia, waters from a creek threatened a suburban subdivision, or a tornado sighting was announced. Often the population evacuated in these situations is not large, and the occasion does not command national attention, but it both saves lives and puts extraordinary demands on the evacuees and emergency management officials. One form of evacuation planning is aimed at making this type of ordinary movement smooth and efficient without much societal disruption. Other situations are more infrequent, yet have occurred and will continue to present risks to communities. For example, a nuclear power plant malfunctions prompting a notification system to be activated, a load of warheads spills from an overturned truck, a volcano awakes from dormancy, a major hurricane is tracking toward the Gulf Coast, or a scientist issues an earthquake prediction.

Local, state, and federal officials may become involved in making a decision to evacuate sizeable numbers of people and then in implementing the evacuation. A second form of evacuation planning is geared toward reducing the impacts of large but rare catastrophic events. At the extreme, some evacuation situations only exist in scenario format and have never been actually experienced. A terrorist group plants a nuclear warhead in a major U.S. city such as New York or Washington, D.C. An incident in the Middle East leads to a Soviet threat of a nuclear strike against the United States. Such scenarios may tax the ability to plan for and conduct an effective evacuation. Thus a third form of evacuation planning is oriented toward unknown and perhaps unthinkable evacuation situations. These three categories of incidents are similar in that they necessitate an orderly and collective emergency response by officials and the public. Evacuation is a protective action process that may ensue because of these events or the threat of them. It may come about through a warning, or because people decide on their own that leaving would be a prudent course of action. The purpose of this study is to examine the topic of evacuation planning in the United States from a critical perspective to determine how it can be improved. This is done for all hazards for which evacuation is a legitimate protective action and under the concept of a generic or integrated emergency planning process. Evacuation is an important protective action for hurricanes, floods, tsunamis, volcanoes, hazardous material accidents, nuclear power plant accidents, and crisis situations such as nuclear war. It is also of relevance for other hazards such as tornadoes or earthquakes, although sheltering is the dominant form of protection. The generic planning philosophy promotes the development of a functional emergency evacuation plan for all of these hazards with details for those situations which require specialized considerations.

1.1 RESEARCH OBJECTIVES

Five research objectives were specified at the beginning of the project. First, the work sought to identify and present issues in evacuation planning. These issues included concerns raised by members of the general public, positions taken by political leaders, and deficiencies identified by scientists. These issues ranged from general global statements, such as the effects of planning on world military stability, to very specific concerns with one aspect of a plan such as the use of school bus drivers to evacuate student populations. Second, the work sought to identify and summarize research conducted on evacuations and to support evacuation planning. This was mainly limited to documents that have been formally published but also included the unpublished materials that we could locate and obtain. Major attention was given to the ability to generalize from specific research efforts to the concept of a generic evacuation plan. Third, the work sought to assess the various issues and concerns identified in light of research findings. Some issues are relevant in light of existing research, others are erroneous, or perhaps misunderstandings. This task is important in that incorrect assumptions adopted in evacuation plans may decrease the effectiveness of evacuation responses. Issues that cut across hazards were also identified and addressed. Fourth, the work sought to identify and analyze those issues not well addressed by existing research. It is hoped that, by legitimizing potential planning problems and deficiencies, efforts can be mounted to minimize the impacts of these issues. Fifth, the work sought to suggest how research could be used to resolve those remaining problems and issues. This includes developing ideas about the types of research needed, how it would help remove problems faced by evacuation planners, and what priorities should be given to new research proposals.

1.2 RESEARCH APPROACH

Conducting a "state-of-the-art assessment" is not governed by any standardized method other than the general premises of scientific research. With this in mind, the research was structured into five tasks.

1.2.1 Literature Review

The first task was to identify the relevant body of research pertaining to evacuations and evacuation planning. The bibliography of all research sponsored by the Federal Emergency Management Agency (FEMA) and FEMA predecessors was reviewed and all relevant documents were identified. In addition, various planning guides relevant to evacuation were obtained from FEMA. Other evacuation literature was identified based on recent evacuation studies (Quarantelli, 1980; Perry et al., 1981; Sorensen and Richardson, 1984; Mileti, 1975; Drabek; 1986; 1983; Rogers and Nehnevajsa, 1984). In addition, discussions were held with

various experts in the field to identify materials not easily accessible.

1.2.2 Analytical Framework

Task two was the development of an analytical framework to guide the research effort. The framework serves as a heuristic to aid in sorting information contained in the research literature and to help identify generic issues and problems. The components are listed in Table 1.1. "Hazard Characteristics" refers to the event being studied or researched. Relevant dimensions of hazards that may affect evacuation planning include the size of the area at risk, the speed of onset of the event which affects the time available for decisions and population movements, the potential destructiveness of the event, and the type of causal agent. "Warning Characteristics" refers to the nature of the warning effort to support evacuation. Relevant factors include the actual amount of lead times and variability in those times, the nature and level of effort placed in the warning effort, and the style and content of warnings. "Social Characteristics" refers to population and human factors which may influence behavior. Factors such as previous experiences, presence of special populations (non-English speaking for example), or unique geographical settings are included in this category. "Organizational Characteristics" refers to the infrastructure surrounding the evacuation effort. Relevant factors include the level and type of evacuation planning and general quality of emergency response planning, the level of staffing and personnel available for planning and response, and the particulars of equipment needs and supplies. "Response Characteristics" refers to the implementing stage of evacuation. Relevant factors include the size of the evacuating population, possible or intended destinations, travel modes, risks encountered in evacuating, and other feasible protective actions. Taken together all of the factors in the analytical framework helped to shape the work conducted in the next task. This framework also serves to organize the evacuation planning issues presented in the next chapter and to analyze those issues in light of research findings. The summary of those findings by each of these five factors is presented in Chapter 6.

1.2.3 Abstracting and Coding

Information was synthesized from the research literature in two ways. First, for every study identified, an abstract was prepared. These ran from about 200 to 1000 words in length depending on the size and complexity of the document. The abstract describes the study topic, approach, and general contributions. When a document covers more than just evacuation, the abstract emphasizes the evacuation-related materials in the context of its total scope. In addition, specific findings have been included in point form following the text of the abstracts when appropriate. These abstracts are published in a companion document (Vogt and Sorensen, 1986). Based on the concepts

Table 1.1. Analytical framework

Physical hazard characteristics
Ability to specify hazard parameters
Ability to detect hazards
Hazard dimensions
Threat or risk of hazard
Warning characteristics
Ability to alert
Style and content of warning
Social characteristics
Risk perceptions
Ability to receive warnings
Ability to evacuate
Organizational characteristics
Planning and plans
Training of evacuation personnel
Technical basis for evacuation planning
Response characteristics
Constraint to evacuation
Public behavior
Emergency worker behavior
Evacuation as a public good

developed in the analytical framework, a coding form was developed to characterize all empirical studies. The major purpose of the codings was to allow an assessment of the robustness of and ability to generalize the research findings. The coding form is reproduced in Appendix A.

1.2.4 Critical Issues Identification

The fourth task was to inventory potential issues surrounding evacuation planning across the range of hazards covered by this research. This was accomplished in several ways. First, some issues emerged from the research literature itself, particularly from accounts of evacuations which detailed various problems encountered during the events. Second, newspaper articles from the AP and UPI concerning evacuation planning for nuclear and chemical incidents for the last five years were reviewed. Third, various written critiques of evacuation planning were reviewed. Fourth, administrative and civil litigation concerning evacuation and planning was reviewed. Fifth, Congressional Hearings that covered evacuation were reviewed when identified. Finally, project staff discussed issues with FEMA staff and state and local planners to gain a picture of practical evacuation problems. An inventory of issues raised is presented by hazard in Appendix B. That a point is listed in this inventory does not suggest it is valid or meaningful but reflects a statement or position revealed by one or more of the above efforts.

1.2.5 Integration

The final task was to compare the issues identified in the previous task with the knowledge and findings in the research literature. This was done to identify the areas in which evacuation planning suffers from inadequate research and to determine which issues are valid and could be potentially resolved by further efforts. The results of this task summarize weak areas in evacuation planning as they exist cross-hazard and present a long-range research agenda to support evacuation planning under the integrated planning concept. A schematic diagram outlining the timing and relationships among tasks is shown in Fig. 1-1. To maintain some objectivity, the development of the issues inventory (Task Four) was conducted separately from the abstracting and coding (Task Three). The integration of these two tasks (Task Five) results in a relatively objective assessment of the issues.

1.3 EVACUATION AS A SOCIAL PROCESS

Evacuation is the collective mass movement of people and property away from a source of potential threat of injury, death, or damage and the return after the threat dissipates. As defined, evacuation is not a stimulus/response type of behavior. It is viewed as a process by which people form images of threat or risk and come to act upon the available

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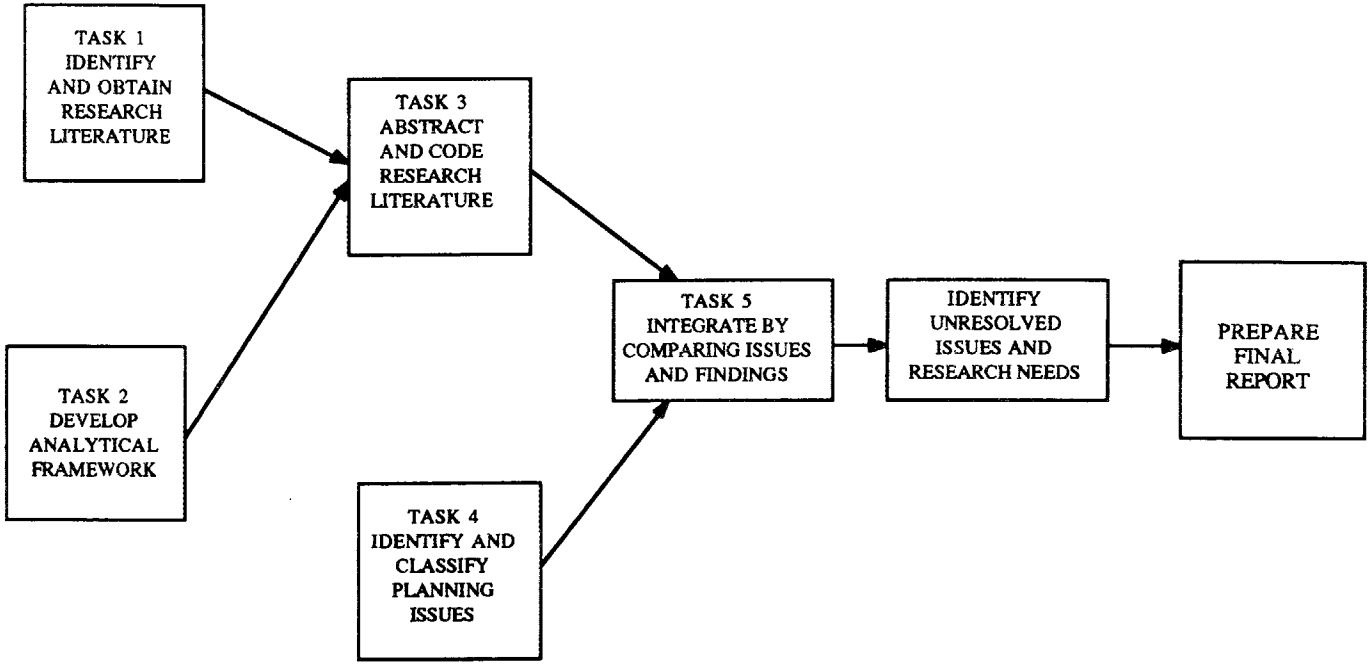

Fig. 1-1. Project tasks.

information in setting a course of action or inaction. Evacuation is also used here to describe movements of significant groups of people. While it is inappropriate to define a precise threshold of how many people must leave to constitute a collective movement, it is clear that it is not a person escaping from a burning car, or a person taking evasive action from an aggressive person (Wenger, 1985b). Evacuations are sometimes distinguished as to whether they are precautionary or protective. Precautionary evacuations are defined as those in which people move away from a potential threat that fails to materialize. Protective evacuations are defined as those in which people move away from a threat that occurs. In part this distinction is somewhat artificial in that both types are conducted to protect the public, only in the former a post-analysis shows it was not needed. Often what starts as a precautionary evacuation becomes protective when the event does occur.

It is rare that evacuations are carried out forcefully or by police order. Most evacuations involve some degree of human judgements in which members of the public are given some freedom of choice. The degree to which public officials and emergency or law enforcement personnel impose a sense of force to evacuation may range from mild recommendations to forceful removal. The norm is somewhere in between. Policies and laws on this matter as well as who has the authority to recommend an evacuation vary according to state and community. As defined, evacuations are round trip events. They involve movement away and movement back into the area at risk. This latter facet is frequently overlooked or not emphasized in the conceptualization of evacuation research. Evacuations involve a temporal as well as a spatial nature. Some evacuations, such as for hazardous material incidents or volcanic eruptions, may turn into an extended evacuation or a semi-permanent relocation. Ultimately this may lead to permanent migration. The exact time threshold between evacuation and permanent population migration, however, has not been defined.

Drabek and Stephenson (1971) identified four types of evacuations. An evacuation by invitation occurs when someone outside the area at risk provides the means or impetus for someone at risk to leave. Evacuation by decision or choice involves individuals processing warning information to arrive at a decision to leave and then take action. Evacuation by default involves behavior dictated by actions other than seeking safety from the hazardous event. Evacuation by compromise is characterized by people following orders even though they do not desire to leave.

Perry (1985) differentiates four types of evacuation using the concepts of the timing of the movement and the length of the stay. By categorizing the two dimensions into dichotomous variables: pre-impact/post-impact/short- and long-term and, developing a two by two matrix based on these distinction, the four types are identified. "Preventive" evacuations are short-term movements prior to impact. "Protective" evacuations are pre-impact movements over a long-term time frame. "Rescue" evacuations are short-term movements of people out of

the impact zone immediately after the impact. "Reconstructive" evacuations are the long-term movements that occur after the impact period. Perry also distinguishes among voluntary and coercive evacuation. Evacuations involve a series of organizational and individual or family decisions. At the organizational level the following decisions are frequently made in most potential evacuation situations:

1. whether to notify,
2. whether to evacuate,
3. areas to evacuate,
4. when to issue warning,
5. channel to communicate,
6. nature of recommendations and instructions,
7. content of evacuation notifications, and
8. when to return.

At the individual or family level comparable types of decisions include:

1. whether to evacuate,
2. when to evacuate,
3. what to take,
4. how to travel,
5. route of travel,
6. where to go, and
7. when to return.

The nature of these decisions helps to illustrate that evacuation is a complex social process and not a stimulus/response event. While these decisions are being made, considerable communication and social interactions occur. As a result evacuation planning is not a perfect science and at times is a highly politicized topic. In the next chapter we review the issues that have emerged from experiences with evacuation planning.

2. EVACUATION PLANNING ISSUES

2.1 INTRODUCTION

The purpose of this chapter is to identify and discuss issues that have been raised concerning evacuation in the event of various hazards. Some issues have been raised by researchers and the scientific community, others by concerned citizens, and still others by critics using evacuation issues as a means to address other social controversies. Some of these issues have generated significant public concern and debate while others have been academic issues. These issues and beliefs are important because they represent challenges to the feasibility and effectiveness of evacuation planning, and some can potentially provide the means to improve evacuation implementation if addressed. The extent to which these issues can be eliminated or dismissed on the basis of current physical and social science knowledge is important both for assessing the viability of evacuation as a protective action strategy and for eliminating unneeded research. Where valid, it is important that evacuation planning incorporate knowledge concerning the issues. The extent to which an issue is unresolvable is also important for establishing agendas for new research on evacuation. Where invalid, examination of the issues is important to prevent erroneous issues from interfering with sound evacuation planning or even from leading to poor evacuation plans.

The issues identified in this chapter come from a variety of sources including research reports, critiques of evacuation planning, editorials, transcripts of hearings, litigations, and newspaper articles. Issues were summarized in a point form for each hazard. A conceptual typology of five major issues was induced from these lists, and a hierarchy of issues was specified under these five categories. The issues were then systematically reviewed, and the hazards affected by each issue were identified.

The major categories of issues and their definitions are as follows:

- Physical Hazard: the nature of the threat including the definition of areas at risk, lead time, location, magnitude, probability, and type of causal agent.

- Warning: the nature of the information dissemination process including the ability to notify and provide a warning message, the quality of the information, and timing of the message delivery.

- Social: the pre-evacuation population attributes including psychological, demographic and social characteristics.

- Organizational: the attributes of emergency preparedness and response organizations.

- Response: the behavior of people and organizations in an evacuation.

2.2 PHYSICAL HAZARD ISSUES

2.2.1 Uncertainty in Ability to Specify Hazard Parameters

The ability to make evacuation decisions depends on knowing the nature of the hazard creating the threat. This includes the following dimensions:

1. location,
2. timing,
3. magnitude,
4. effects, and
5. secondary hazards.

2.2.1.1 Location

The ability to specify the location of hazard impacts is critical to good evacuation planning because officials need to know which areas to evacuate, given the specific threat. This question has been raised as a planning problem and issue for hurricanes, earthquakes, tsunamis, floods, tornadoes, nuclear power plant accidents, hazardous material accidents, and for nuclear crisis situations.

Hurricanes have very uncertain points of impact. At 48 hours before landfall, errors are large (250 miles or about a 600- to 700-mile stretch of coast). At 24 hours before estimated landfall, the forecast error for the storm is about 100 to 125 miles. This translates into a potential evacuation zone of 300 miles along the coast. It is estimated, however, that it will prove necessary to evacuate only a fraction of this area to preserve public safety. Thus, the decision dilemma for local officials is whether or not to order an early evacuation of a 300-mile-long area of the coast knowing that, 75 to 85% of the time, they will be evacuating unnecessarily. Furthermore, this decision is confounded by the largely unknown cost of evacuating large areas and the perceptions of liabilities for being wrong for either evacuating unnecessarily or failing to evacuate prudently. At 12 hours, the forecast error is reduced to less than 50 miles, but it may be too late to order and implement an effective evacuation, because winds and surge may prevent vehicular movement during about three hours before landfall. Even at 12 hours, the storm may suddenly veer and hit an area outside the forecasted landfall zone.

Since earthquake prediction is a relatively undeveloped science, the ability to specify the location of a quake and the areas it will

affect is highly uncertain. Existing instrumentation does not cover large geographic areas that are potential earthquake risks. Areas in the midwestern and eastern United States have the potential for earthquakes, but the ability to predict in these locations is highly uncertain. In areas being studied by geoscientists, identification of hazardous structure and earthquake-prone areas could provide the basis for selective evacuation should the scientists issue a prediction of an impending quake.

In tsunami evacuation planning, hazard risk zones are defined by modeling historic tsunami run-up heights. In some locations the coastal floodplain definition is used as a surrogate measure. These definitions have not been developed for all risk areas. In some cases where tsunami run-up zones have been estimated or recorded, their accuracy has been challenged.

Areas at risk from floods are defined under the hazard mapping program of the National Flood Insurance Program (NFIP). The accuracy of these maps is largely acceptable as a basis for evacuation planning, but in some locations they may underestimate the area at risk due to development in upstream water basins.

The tracks of tornados cannot be predicted, given current knowledge about storm behavior. Funnel clouds cannot be tracked on conventional radar systems. Due to the lack of ability to forecast tornado tracks, large areas are defined to be at risk from a storm capable of spawning a tornado. This practice has received some public criticism.

The ability to specify volcanic hazards for evacuation became an issue following the eruption at Mount St. Helens, Washington, in 1980. Critics raised the issue in conjunction with the lateral blast which covered a larger area than anticipated. Furthermore the resulting ashfall covered areas considered by public officials to be safe from volcanic risks.

The area at risk for a nuclear power plant accident is a function of source term and meteorological conditions. There is some controversy at present about the size of the source terms and the area they would affect. The Chernobyl reactor accident in the Soviet Union (1986) has raised new issues about areas at risk because the area impacted was much larger than expected.

The definition of areas at risk from hazardous materials accidents has become a major issue since the 1984 accident in Bhopal, India. Since that event, critics have challenged companies to define the areas that can be impacted by an accident and to specify the types of potential chemical releases.

Many critics of evacuation planning for nuclear war say that it is impossible to identify risk areas because everything is at risk from the radiation hazard and that there will be no safe areas. Others have challenged the targeting scenarios used to develop plans.

2.2.1.2 Timing

Uncertainty in the timing of an event is an issue in evacuation planning because it effects the ability to decide when to evacuate. The dominant issue for hurricane evacuations is the timing of official evacuation orders. This is problematic due to the long lead times that have been estimated to be required to evacuate coastal areas at risk. Not only is location uncertain at 24 hours but so are time of landfall and storm intensity. The average time error may be around six hours. Storms may also intensify rapidly or reduce in intensity thus affecting timing of impact.

A major issue concerning earthquakes is the ability to specify an accurate time window in which the earthquake will occur. Scientists are sure that a major earthquake will occur in Southern California during the next 20 years, but they cannot be more specific.

A constraint to effective volcano evacuations is the ability to predict the time of major eruptions. The lack of this ability means that evacuations may be ordered prematurely during periods when evidence suggests an increased probability of eruption. This has been criticized by residents and other persons who have economic interests in the areas at risk.

2.2.1.3 Magnitude

Issues regarding the prediction of the magnitude of impact covary with issues on prediction of the area at risk when the magnitude of a hazardous event determines the size of the area impacted. The above discussion of issues regarding the areal definition of threat are applicable to the definition of magnitude and will not be repeated. In addition, the following issue is relevant for flash floods. The volume of water coming from any storm is difficult to accurately predict. This has been raised as an issue in arid environments where the volume of flood water has been underestimated in previous floods.

2.2.1.4 Impacts

Uncertainties regarding the effects of radiation are an issue in evacuation planning for nuclear power plant accidents. Critics say that the lack of knowledge about the effects of radiation on human health, referred to as dose response, creates uncertainty in making a protective action decision.

2.2.1.5 Secondary and multiple hazards

Volcanoes, hurricanes, and earthquakes all have multiple hazards for which evacuation is a viable component of protective action. The

ability to detect and specify the nature of these hazards is important to effective evacuation planning and public safety.

Tornadoes are spawned by most hurricanes as they move inland. The tornadoes may cause more casualties than the storm itself, yet emergency response remains concentrated on the direct hurricane impacts, such as coastal flooding, and not on the tornadoes.

Earthquakes can trigger landslides, dam failures, nuclear power plant accidents, hazardous materials releases, gas line ruptures and other secondary hazards. Knowledge on the conditions that might cause earthquakes to create such hazards is not adequate.

Associated with volcanic eruptions are numerous threats including mudflows, pyroclastic flows, blast, lava flows, and ashfall. These can create secondary threats such as reservoir failure or overtopping and snow-melt-induced flooding. Following the eruption of Mount St. Helens, criticism was that officials did not adequately consider all of the secondary effects in their emergency response.

2.2.2 Uncertainty in Ability to Detect Hazards

Inability to recognize that a threat exists makes it impossible to issue an evacuation warning or to encourage people to move away from the threatened area. Two issues have been identified in this regard:

1. scientific ability, and
2. lack of physical cues.

2.2.2.1 Scientific ability

Some hazards pose difficulties for using evacuation as a protective action because the onset of the hazard is difficult to detect, let alone specify. Many dams that are potentially unsafe are not monitored, and failure would be difficult to detect except by observation or measurement of the increased flow of water which may come too late to effectively evacuate areas below a dam. A major issue for tsunamis (both local and distant) concerns false alarms. The problem of detection is more severe for local tsunami events; seismic activity, the only current means of timely detection, may only generate a tsunami on a rare occasion, but it is the only warning that can prompt immediate evacuation. Distant tsunamis can be more readily detected, but whether or not and exactly where effects will occur is not well understood.

Detection technology and techniques for measuring harmful amounts of chemicals or other hazardous materials are not available or installed at locations where accidents can occur. It is, therefore, difficult to detect a release of hazardous materials until humans are exposed. Recently, chemical plants have been criticized for the use of "human canaries" to detect leaks.

2.2.2.2 Physical cues

Critics of nuclear power hold that because radiation is invisible, the public at risk will not be able to see the hazard and, therefore, will not take protective action. An additional issue is that people who do evacuate will not know where radiation exists and may be exposed during an evacuation.

2.2.3 Hazard Characteristics Constrain Evacuation Effectiveness

The speed of onset of some hazard events is a major problem for effective evacuation for a subset of hazards. Without adequate lead time, it will be difficult to effectively move threatened populations. Scientists may detect a large earthquake hours to minutes before occurrence. Floods can have very rapid onset, and there may be only minutes in which to issue a warning before they become hazardous to human safety. Local tsunamis generated immediately off-coast have lead times of five to ten minutes before impact. Explosive-type volcanoes may have no lead time for explosive effects and very short lead times for other effects such as mudflows and pyroclastic flows. Many accident scenarios for hazardous materials have lead times ranging from zero to 30 minutes. One attack scenario for a nuclear crisis estimates a 20-minute lead time after a strike is initiated.

2.2.4 Planning Increases the Threat or Risk of Hazard

Critics have argued that planning increases the likelihood of nuclear war and nuclear power accidents. A related issue that is more relevant and of greater importance is whether evacuation plans increase the threat or consequences of a hazard if it occurs.

2.3 WARNING ISSUES

2.3.1 Uncertainty in Ability to Alert

Most people would evacuate after receiving a warning to do so. The inability to warn people to evacuate results in greater exposure to risk. The following issues deal with this inability to alert populations at risk:

1. lack of warning systems,
2. timing of warnings,
3. information withholding,
4. inadequate communication,
5. risk not revealed,
6. warnings not issued to certain groups, and
7. sirens not heard.

2.3.1.1 Lack of warning systems

Critics have argued that existing warning systems are not adequate to inform the public to evacuate. For example, few facilities that use dangerous quantities of hazardous materials have a warning system that could alert the public of a release of materials that would affect off-site populations.

Due to funding problems, few emergency plans have been developed for public dams, even though federal policy requires them. Virtually no plans exists for dams that are privately owned. In the United States, only a portion of the communities that have the potential for flash flooding have installed a local flash flood warning system to support evacuations.

2.3.1.2 Timing of warnings

The speed of onset of some hazards dictates that warnings be issued in short time frames. Critics of evacuation plans for these hazards claim that warning systems are not in place to provide timely information; therefore, evacuations are not feasible.

2.3.1.3 Warnings and information will be withheld

Public doubts have arisen regarding persons and organizations involved in the evacuation warning process withholding information from the public. This issue has surfaced in connection with earthquakes, nuclear power, and hazardous materials. Some people feel that should an earthquake be detected, the information would not be made public for fear of causing alarm. Opponents of nuclear power have litigated that utilities would try to cover up an accident instead of reporting it to local officials because of their vested interest in keeping the plant operating. Large chemical companies have been criticized for not warning the public following releases of chemicals.

2.3.1.4 Inadequate organizational communication

Poor abilities to communicate constrain issuing a warning for an evacuation. The National Weather Service (NWS) has identified poor communications as a problem in the case of flash floods. This issue has been litigated at several nuclear power sites. It is also beginning to emerge as an issue for hazardous materials accident planning.

2.3.1.5 Risks not revealed to warning organizations

Intervenors in nuclear power licensing hearings claim that the true risks of an accident are not provided by companies in an attempt to downplay public opposition. At sites where hazardous materials are

stored, companies withhold information on the chemicals to protect proprietary information on production processes.

2.3.1.6 Warnings will not be issued to transient populations

Transients are defined as people in an area at risk that live somewhere else. Typically transients are people traveling through an area or vacationers. In some hurricane situations, it would be difficult to communicate sufficient warning information to large tourist populations (e.g., in the Florida Keys), so they could evacuate effectively. Litigation over nuclear power plants, such as Seabrook in New Hampshire, has focused on the issue of the difficulty in warning people in recreational areas and seasonal tourist populations.

2.3.1.7 Siren systems cannot be heard

This issue concerns conditions under which sirens are not heard by people at risk. At the Shearon Harris Nuclear Power Plant, intervenors maintained that sirens cannot be heard inside residences at night when air conditioners are operating. Following the Bhopal, India, accident citizens in Institute, West Virginia, complained that sirens were always sounding at chemical plants, so no one listened to them.

2.3.2 Information Constrains Evacuation

People may receive a warning, but the information in that warning may not lead them to evacuate or to go to the best location. Specific issues include the following:

1. special terminology,
2. probabilistic information,
3. multiple messages,
4. inadequate content,
5. credibility,
6. frequency, and
7. siren use.

2.3.2.1 People don't understand warning special terms

The NWS uses special warning terminology to designate the appropriate level of preparedness and vigilance for a possible tornado, hurricane, or flood threat. These terms include alert, watch, and warning. Some people feel that these terms are ambiguous and that people do not understand the differences between them.

2.3.2.2 Probabilities are not understood or are misinterpreted

An argument against using probabilities in hurricane warnings was that it would discourage evacuation because the probabilities would always seem low. In developing policies regarding earthquake predictions, scientists maintain that people won't understand the probabilities in a prediction.

2.3.2.3 Multiple messages create confusion

In recent hurricanes, the National Hurricane Center, state officials, and local government authorities gave different advice about evacuating which created some confusion. At Mount St. Helens, public officials felt that the media's sensationalization of the volcanic threat created problems for evacuating threatened populations by emphasizing topics such as convergence behavior and people refusing to leave.

2.3.2.4 Warning content is inadequate

The messages telling people to evacuate from hazardous areas may not be adequate. In a recent flash flood in Cheyenne, Wyoming, a post audit found that messages may not have been emphatic enough to prevent people from reentering flooded areas. Intervenors charge that sample messages prepared by planners for nuclear power accidents are inadequate. Critics of evacuation planning for nuclear crisis charge that no amount of information will convince people that a war is imminent.

2.3.2.5 Warning credibility

People will not believe warnings that an evacuation is needed if they come from organizations with low credibility. It has been argued that companies that operate nuclear power plants are not a credible source of warning information. In a nuclear crisis situation, some critics maintain that people will not believe that a crisis exists because no warning will be credible.

2.3.2.6 Frequency of information

Following Hurricane Diana, people thought that information was not given out frequently enough by the NWS. In many emergencies the public complains about not receiving enough information to make appropriate evacuation decisions.

2.3.2.7 People do not understand sirens

In tsunami-prone areas, people have complained that they cannot distinguish between the different siren signals that depict the onset of different hazards. In nuclear power accidents, critics maintain that people will think the sirens are false alarms or tests; therefore, they will not respond when a real emergency occurs.

2.4 SOCIAL ISSUES

2.4.1 Social Factors Color Risk Perceptions

At issue is that pre-emergency risk perceptions bias human evacuation behavior in case of an emergency. These issues include the following:

1. mitigation measures,
2. prior experience,
3. depersonalization of threat,
4. fear of radiation,
5. denial of hazard,
6. denial of need for preparedness, and
7. false alarms.

2.4.1.1 Mitigation measures create a false sense of security

People may believe that they are protected by some type of engineering mitigation structure which leads them to believe they do not need to evacuate. For hurricanes, this may be a sea wall such as the one on Galveston Island, Texas. In flood plains, these structures may be dams or levees. In a dam failure situation, people living below the dam may fail to consider that the dam can overtop or collapse.

2.4.1.2 Experience

At issue is how prior experience with an evacuation affects subsequent evacuation behavior. This issue has been chiefly raised in the context of hurricane and tornado planning. Some officials feel that experience with an event creates overconfidence in dealing with subsequent events. Others maintain that people who have experienced an evacuation event would be more likely to evacuate if advised to do so. Another related issue is that of false alarm (see below).

An issue in nuclear crisis planning is the lack of experience with a nuclear war or conventional war. Critics assume that, since a nuclear war has never been experienced in the United States, response would be different from all other hazards. Planners tend to assume that the population would not respond to an evacuation based on any previous war-related experiences.

2.4.1.3 Depersonalization

Depersonalization has been raised as an issue for earthquake prediction planning. It is believed that while people in California know there is a threat they would discount their personal risk in the event of an earthquake prediction because their house or neighborhoods would not be affected.

2.4.1.4 Fear of radiation

Nuclear power evacuation planning critics feel that radiation is a unique threat and that, because of the great fear of radiation, the public would behave differently when warned to evacuate. The differences cited have included panic; a psychic numbing, rendering people incapable of evacuating, and chaotic flight behavior.

2.4.1.5 Deny the hazard exists

This issue involves the public perceiving that an event is not hazardous or cannot cause harm. In flash floods, it involves possible perceptions that waters flowing at high velocities are not dangerous. A second example involves people who reside near hazardous material sites and believe that nothing harmful is used or produced.

2.4.1.6 Lack of preparedness

The lack of preparedness has been raised as an issue for nuclear war emergency planning in the context of lack of support for or opposition to such planning. The feeling is that people who do not believe in or who oppose planning would not follow an evacuation order or recommendation if one were issued.

2.4.1.7 False alarms

The false alarm issue is raised for many hazards including hurricane, earthquake, tsunami, tornado, nuclear power, and nuclear crisis. The basic issue is that people who evacuate unnecessarily will not evacuate in a future event. The extreme case of this is for a nuclear crisis. Some critics feel that only one evacuation could be ordered and if that proved wrong no one would evacuate a second time.

2.4.2 Factors Color the Ability to Receive Warnings

At issue is whether social characteristics affect the way in which people understand an evacuation warning and thus lead to misinterpretation. Specific characteristics include

1. culture and ethnicity,
2. disbelief in ability to detect or predict, and
3. lack understanding of risk.

2.4.2.1 Culture and ethnicity

The issue is that evacuation warnings are not geared to ethnic, racial, or non-English-speaking groups but to the dominant population groups. As a result minority groups could be more vulnerable because they are less likely to receive or understand a warning message and, so, are less likely to evacuate.

2.4.2.2 Disbelief in ability to detect or predict

Some people do not trust the ability of scientists or other hazard monitors to accurately predict events such as an earthquake or a nuclear crisis emergency, and, as a result of their disbelief, they would not evacuate to safety.

2.4.2.3 Lack of understanding of risk

Some people do not understand the nature of risks from nuclear power plant accidents, even when told in a warning. A consequence of not understanding would be to delay evacuating and remain at risk.

2.4.3 Factors Affecting the Ability to Evacuate

The issue is that certain population characteristics constrain people's ability to evacuate even if they are adequately warned. These include

1. economic resources, and
2. special or institutional populations.

2.4.3.1 Economic resources

This issue concerns the constraint of monetary resources on the public's ability to evacuate. The contention is that some people will not evacuate because of the direct expense of leaving and the possibility of loss of income. These people are more likely to be in the lower income brackets.

2.4.3.2 Special or institutional populations

The issue is whether special populations and institutional populations require specialized assistance to evacuate. The key

parameters for an effective evacuation are the unique problems of these populations and the specific needs of the different groups or institutions.

2.5 ORGANIZATIONAL ISSUES

2.5.1 Planning Elements are Inadequate

A series of issues have been raised about the scope and content of evacuation planning for a variety of hazards. Specific issues include

1. lack of coordination in planning,
2. inadequate planning for shelters,
3. lack of plans,
4. planning for secondary hazards,
5. definition of emergency planning zones (EPZ),
6. plans for institutional facilities and special populations,
7. planning for reentry, and
8. no support for planning.

In addition, several issues are unique to evacuation planning for nuclear crisis or the CRP concept. These include

1. planning for emergency resources to support evacuees,
2. planning for medical and health care of evacuees,
3. planning for extended evacuations, and
4. planning that uses the wrong assumptions.

2.5.1.1 Lack of coordination in planning

Planning for evacuations is done by separate jurisdictions and different levels of government. This issue concerns whether or not these plans are coordinated and, if not, if the absence of coordination will lead to ineffective evacuations. After Hurricane Elena, local officials complained that the National Hurricane Center and state government officials' lack of coordination with local government authorities hindered evacuation. This type of concern has been raised for earthquake prediction and hazardous material accidents as well. In the later case, transportation accidents create coordination problems that are not well addressed by plans.

The issue of coordination of plans has developed in nuclear power plant planning where local governments have refused to participate in planning efforts for that specific hazard. Another example of this issue is the lack of coordination of planning for a nuclear crisis situation, particularly between high- and low-risk areas or with communities that refuse to develop plans to participate in relocation.

2.5.1.2 Inadequate planning for shelters

Three shelter issues have been raised for different hazards. First is the feasibility of vertical evacuation in hurricanes. Second is the ability to evacuate people to decontamination shelters in the event of contamination from a nuclear power or hazardous material accident. The third concerns the adequacy of shelters necessary for large-scale evacuations as would be required in a nuclear crisis situation.

2.5.1.3 Lack of plans

A major issue is the extent to which plans are lacking and whether a lack of evacuation plans would constrain evacuation effectiveness. This topic is raised as an issue for earthquake predictions, flash floods, dam failures, tornadoes, hazardous material accidents, and nuclear crisis situations. Since earthquake prediction is an emerging science and is largely unproven, the issue is the extent to which a community and state should plan for an emergency. Furthermore, if more specific warnings can be issued as in the case of the earthquake that has been predicted for Parkfield, California, the issue is whether or not detailed plans are needed. Many communities have no plans for infrequent events such as a flash flood, a dam failure, or a rare tornado. Even for frequent events, such as hazardous material accidents, evacuation planning is largely lacking at both state and local levels.

2.5.1.4 Planning for secondary hazards

Knowledge of such events may not be as good as desired but even existing knowledge has not been applied to developing comprehensive emergency plans that include evacuation. The three situations, in addition to those discussed earlier, are a natural hazard, such as a hurricane or flood releasing hazardous materials; a tornado, coinciding with a flash flood; and an earthquake-induced nuclear power plant failure.

2.5.1.5 Definition of emergency planning zones (EPZ)

This has chiefly been an issue at nuclear power plants, although minor issues regarding delineation of special planning zones have surfaced for other hazards. At issue is whether the size of the planning zone covers the true area at risk and whether evacuation is feasible outside the detailed planning zone because of the lack of detailed evacuation studies.

2.5.1.6 Plans for institutional facilities and special populations

This issue concerns whether or not detailed plans are needed to evacuate special populations such as the hearing-impaired or mobility-impaired, or institutional populations such as schools, hospitals, nursing homes, or correctional facilities. Second, if such plans are lacking, what information should they include. While this is an issue for all hazards, it has been raised chiefly by intervenors in nuclear power plant hearings and critics of crisis relocation planning (CRP).

2.5.1.7 Planning for reentry

Reentry has been noted as a problem in studies of some evacuations (e.g., during Hurricane Diana and the Mississauga train derailment). Issues associated with reentry include (1) deciding who should be allowed into evacuated areas before the general population and (2) managing the people who converge on the area at risk simply to observe the event.

2.5.1.8 No support for planning

This issue concerns whether opposition to planning or non-support for planning constrains the development of plans and the implementation of an effective evacuation. It has been raised primarily in the case of CRP and nuclear power plant accident planning.

2.5.1.9 Planning for emergency resources to support evacuees

This issue has also been raised for nuclear crisis situations. Critics have questioned the ability to develop plans that can guide the redistribution of resources to support large relocated populations. These resources include food, water, fuel, and other basic requirements to support subsistence living of evacuated populations.

2.5.1.10 Planning for medical and health care of evacuees

Evacuees typically include people who require special medical attention, particularly those from health care facilities but also include people who normally reside at home. Whether or not plans are adequate to support relocation of people with health problems has been raised as an issue for large evacuations (such as in a nuclear crisis). A related issue is the inadequacy of planning for mental health care needs of evacuees.

2.5.1.11 Planning for extended evacuations

An extended evacuation is one in which people evacuate and the threat lingers, creating problems for defining time of reentry. At issue is the adequacy of plans for providing information and resources to support large numbers of evacuees over long periods of time. For small-scale events with no immediate resolution of the threat, the issue is the adequacy of planning for temporary or long-term relocation, such as at Love Canal, New York.

2.5.1.12 Planning that uses the wrong assumptions

This is an issue in planning for nuclear crisis situations. Critics argue that analyses employ biased assumptions to make evacuations appear feasible. Changing the assumptions would show that it is infeasible and, therefore, an inappropriate protective action.

2.5.2 Training of Evacuation Personnel is Inadequate

Evacuations are supported by a variety of emergency personnel who often perform different tasks including warning, transport, traffic control, law enforcement and the like during an evacuation. The issue has been raised at nuclear power plants that these types of workers have not been adequately trained to support an evacuation. The issue of training has also been raised for emergency personnel such as police and fire departments responding to a hazardous materials accident.

2.5.3 The Technical Basis for Evacuation Planning is Inadequate

Another set of issues regarding planning is the lack of data or information on which to base the planning. These include

1. evacuation time estimates are inaccurate,
2. plans will lead to unnecessary evacuation,
3. organizations for developing plans are lacking,
4. organizations with responsibilities downplay the hazard,
5. knowledge not transferable, and
6. dissemination of technical knowledge is poor.

2.5.3.1 Evacuation time estimates are inaccurate

A variety of models exists to estimate the time it takes to evacuate geographical areas. Different model types are used for different hazards, and some variations are used for the same hazard. Issues have been raised about which models are appropriate to use and whether or not the results are valid. Many of the issues regarding validity involve the assumptions used in the models. Some of the major assumptions that have been challenged include mobilization time,

departure time, road capacity estimates, impacts of bottlenecks, number of vehicles used per household, impact of accidents, route selection, and effectiveness of traffic control.

2.5.3.2 Plans will lead to unnecessary evacuation

This issue has been raised for hurricanes. The current plans call for evacuation decisions to be made at least 24 hours before expected landfall. Critics say this leads to unnecessary costs and risks and that a new planning basis is needed to avoid these unnecessary costs and hardships.

2.5.3.3 Organizations for developing plans are lacking

This issue has been raised regarding fixed-site hazardous materials and their transportation. The issue is that the technical information used to define risks is inadequate for evacuation planning because there is no organization in place to develop the information, to disseminate it, or to apply it.

2.5.3.4 Organizations with responsibilities downplay the hazard

This issue has been raised for hazardous material accidents following the Bhopal, India, accident. The issue is that industry and government officials are reluctant to admit the risks of hazardous technologies because they do not want to get involved with developing plans. This is also an issue for earthquakes and for dam failures.

2.5.3.5 Knowledge not transferable

A general planning issue questions the applicability of information developed from research and experience involving one specific hazard to planning for another. Critics argue that the uniqueness of nuclear power accidents or a nuclear crisis precludes any application of knowledge derived from experience with other events.

2.5.3.6 Dissemination of technical knowledge is lacking or poor

This is an issue of not disseminating the available technical information or issuing needed equipment to implement an evacuation plan. In part, it involves cost, time, and government priorities, and can apply in the case of all hazards, to a certain extent.

2.5.3.7 Populations at risk are unknown

This has been an issue in some disasters (e.g., emergency responders may not know whom to notify nor the characteristics of the population at risk). Such uncertainties are of particular importance should a transportation accident involve hazardous materials.

2.6 RESPONSE ISSUES

2.6.1 Physical Factors Constrain Evacuation

These issues concern the possibility that the geographical characteristics of the area at risk could impede the evacuation process. These include

1. population too dense to evacuate,
2. population in areas with seasonal peaks,
3. boat traffic will interfere with island evacuation, and
4. traffic accidents will constrain evacuation.

2.6.1.1 Population is too dense to evacuate

Many people have questioned the ability to evacuate large, densely populated areas such as New York City, Miami, or Los Angeles in a timely or orderly fashion. Problems cited include lack of transportation, road capacity, traffic jams, and the other litany of issues associated with large-scale evacuations.

2.6.1.2 Population in areas with seasonal peaks

The ability to evacuate tourist and permanent populations from areas having large seasonal populations has been questioned for nuclear power plant accidents and hurricanes. Questions have been raised regarding the organizational ability to warn, transient knowledge of evacuation routes, sufficiency of shelters, behavior of transient evacuees, timing of evacuation, and traffic congestion.

2.6.1.3 Boat traffic will interfere with island evacuation

This is an issue of logistics in certain hurricane settings. Boats going up rivers to seek protection will require drawbridges to be raised. This will delay vehicles evacuating from islands, and evacuees will be trapped.

2.6.1.4 Traffic accidents will delay evacuation

Critics of nuclear power and nuclear crisis evacuation planning have said that traffic accident rates will increase in an emergency evacuation, and the excessive accidents will tie-up traffic trying to leave.

2.6.2 Public Behavior

These issues relate to people responding in a way that will jeopardize the effectiveness of evacuation. These issues include

1. holding parties instead of evacuating,
2. evacuation shadow (excessive evacuation),
3. panic,
4. convergence,
5. spontaneous evacuation,
6. aberrant behavior,
7. failure to use specially designated routes,
8. stress due to evacuation,
9. failure to obey officials,
10. failure to evacuate for long periods of time, and
11. lack of knowledge on how to evacuate.

Again a unique set of issues are found for the nuclear crisis or CRP planning:

12. taking shelter instead of evacuating,
13. not going to designated host areas, and
14. total social chaos.

2.6.2.1 Holding parties instead of evacuating

This is not a major issue, but media accounts report such behavior during hurricanes and other hazardous events.

2.6.2.2 Evacuation shadow (excessive evacuation)

This is a point of litigation at nuclear power plant hearings. Based on the experience at Three Mile Island Nuclear Power Plant (TMI), critics charge that people will evacuate from far larger areas than those officially designated. Because plans do not exist to handle this phenomenon, it is held that evacuations will fail.

2.6.2.3 Panic

Panic is defined as acute fear of entrapment coupled with attempted flight. Critics maintain that people will exhibit this type of response

to an earthquake, nuclear power accident, or nuclear crisis warning. This behavior will lead to increased traffic accidents and abnormal behavior.

2.6.2.4 Convergence

Convergence is the movement of people and vehicles into the area being evacuated for both official and unofficial reasons. It is contended that this behavior will interfere with the flow of traffic leaving an area. In addition, it places population in high risk areas at greater disadvantage.

2.6.2.5 Spontaneous evacuation

Spontaneous evacuation is commonly defined as leaving before the warning to evacuate is given as an official order. The claimed impact is increased congestion on roadways. Another proposed problem of spontaneous evacuation is that it makes zonal or staged evacuations (e.g., evacuating a 2-mile radius, then a 5-mile radius and so forth) infeasible.

2.6.2.6 Aberrant behavior

Aberrant behavior includes looting, antisocial aggressive acts, or other criminal acts. Some believe that this type of behavior would increase during emergencies and would be more prevalent in the event of a nuclear power plant accident or nuclear crisis situation.

2.6.2.7 Failure to use specially designated routes

Traffic time estimates and planning assume that people will use certain optimum traffic routes during an emergency. Critics contend that people will not use those routes; therefore, the evacuation will not be effective. Furthermore, congestion will occur on the routes that people try to use, or routes will be used that place evacuees at higher risk.

2.6.2.8 Stress due to evacuation

This issue, mainly raised in the context of nuclear power and war, is that the act of evacuating leads to stress and that this stress is dysfunctional. Furthermore, some critics suggest that stress will not be mitigated because health services will not be provided during or after the evacuation experience.

2.6.2.9 Failure to obey officials

Again this is a point of contention for nuclear power and nuclear crisis emergencies. The issue is that people will disregard traffic control guides or warning instructions while evacuating. Critics also argue that people will disregard traffic signals or roadblocks.

2.6.2.10 Failure to evacuate for long periods of time

This issue is pertinent to long-term evacuations. It suggests that people will return or attempt to return while a threat still exists. This issue is related to reentry. For CRP it concerns the effectiveness of evacuation planning as a strategic defense policy.

2.6.2.11 Lack of knowledge on how to evacuate

The contention is that people will not get information on where to go and, lacking that information, will unknowlingly put themselves at higher risk, or will simply fail to evacuate because they do not know what to do.

2.6.2.12 Take shelter instead of evacuating

This issue is that many people, if ordered to evacuate, would either take shelter or refuse to relocate because they perceive that evacuation would not protect them. This issue has primarily been raised within the context of CRP.

2.6.2.13 Not going to designated host areas

Evacuation planning for CRP assumes people will go where they are told. This issue raises the point that people will not go to designated areas. The implication is that traffic time estimates and resource availability analyses would then be inaccurate.

2.6.2.14 Total social chaos

This issue involves total breakdown of civilization in the face of a potential nuclear attack. Some people believe that the images of war are so terrifying that mass panic, looting, and violence will ensue following a warning. It is contended that planning will increase this problem and not diminish the likelihood of chaos.

2.6.3 Emergency Worker Behavior

These issues contend that emergency personnel will engage in behaviors counter to evacuation goals. These predicted behaviors include

1. role abandonment,
2. denial of evacuees,
3. erosion of leadership, and
4. no outside help.

2.6.3.1 Role abandonment

Role abandonment involves emergency workers leaving their jobs to perform other roles. The main issue concerns the number of workers who will abandon the assigned jobs. A secondary issue is whether such behavior will render an evacuation ineffective.

2.6.3.2 Denial of evacuees

In nuclear crisis situations, it is contented that evacuees will not be allowed into host areas. This would be particularly true for evacuees from large urban areas. The outcome of the denial would be conflict and violence, including racial strife.

2.6.3.3 Erosion of leadership

This issue questions whether or not leadership could be provided to implement an evacuation during a nuclear crisis. Critics maintain that leadership would dissolve, resulting in a complete lack of social order.

2.6.3.4 No outside help to implement plans

Most evacuation planning assumes initial reliance on community resources with outside help over time if necessary. The issue here is whether or not this outside help would be available during a nuclear crisis evacuation.

2.6.4 Evacuation not Perceived as a Public Good

This set of issues challenges the safety goals of evacuation as a feasible protective action option. Included are

1. evacuation puts people at greater risk,
2. people have a right to stay, and
3. evacuations create liabilities.

2.6.4.1 Evacuation puts people at greater risk

The issue is that people are better off if they do not evacuate during certain threats. In hurricanes, it has been suggested that people take shelter in high-rise buildings on the coast because those caught in traffic or those who leave late would be trapped and inundated by storm surge. For nuclear power accidents, the issue is the possibility of increased radiation exposure while evacuating.

2.6.4.2 People have a right to stay

This issue has been raised for hurricanes and volcanoes. Some citizens maintain it is within their rights to expose themselves to risk; therefore, they should have the right to remain in evacuated areas.

2.6.4.3 Evacuations create liabilities

This is a complex issue with several dimensions. One is that by developing plans a governmental entity becomes liable for not evacuating people effectively. A second is that decision makers are liable for damages incurred while evacuating. A third is that liability exists for losses from false alarms. A fourth is that liability is incurred for the stress of a bad evacuation experience. The last is that liability arises for failure to develop evacuation plans.

3. EVACUATION PLANNING: CURRENT EXPERIENCE, PHILOSOPHY, AND PRACTICE

3.1 INTRODUCTION

In this chapter an overview of evacuation planning is provided for each major hazard. Current philosophies are discussed in the context of alternative protective action strategies. Recent experiences with evacuations are identified. Where federal programs have been developed, the basic outline of the program is presented. Where no national program exists, examples of localized programs are given. In the category of natural hazards, hurricanes, floods, tsunamis, and volcanoes are examined; no evacuation planning per se is done for earthquakes or tornadoes. In the category of human-induced hazards, dam failures, nuclear power plant accidents, hazardous materials accidents, and nuclear crisis situations planning efforts are reviewed.

3.2 EVACUATION PLANNING FOR NATURAL HAZARDS

3.2.1 Hurricanes

The United States has had considerable experience with hurricane evacuations in the past ten years. In 1985 alone four storms led to evacuations including Hurricanes Danny, Elena, Gloria, and Kate (USFEMA, 1986a). Elena resulted in the evacuation of an estimated 1.7 million people along the Gulf Coast. Many of the Elena evacuees in Florida evacuated again for Kate. Hurricane Gloria swept up the Atlantic Coast and led to the evacuation of millions. In 1983, Galveston, Texas, was partially evacuated when Hurricane Alicia threatened and eventually hit the coast (Savage et al., 1984). Several years later, Hurricane Diana created confusion in the Carolinas when it stalled off the coast after the Wilmington/Cape Fear, North Carolina region had been evacuated. Hurricane Iwa (1982), a minor storm, was the first hurricane to strike the Hawaiian Islands in many years (Chiu et al., 1983).

Evacuation is the chief protective action used to safeguard the population against hurricanes. As a result, FEMA has developed a comprehensive hurricane evacuation planning process (USFEMA, 1984b; 1983). The nation's coastline has been divided into 22 basins for implementation of the planning process. It is at the basin level that technical studies are done to provide data for preparing state and local plans (U.S Army Corps of Engineers, 1984). The quantitative studies cover five areas:

1. a hurricane hazard analysis,
2. a property and population vulnerability analysis,
3. a behavioral analysis,

4. a shelter availability analysis, and
5. a transportation analysis.

The hurricane hazard analysis involves simulation of hurricanes using computer models. In a study, 300 to 400 hypothetical storms are generated by varying hurricane intensity, size, direction, and speed. The National Weather Service developed two models, SPLASH and SLOSH, for use in these studies. SPLASH is used for open coastlines. SLOSH is used for bays or estuaries and has the ability to handle unique topographic features and ocean bottom characteristics. Both models have been fine-tuned using historical hurricane run-up data and have an error term of about 20%.

Information provided by the SLOSH models include estimates of the height of water from storm surges, time histories of surges at specified points, wind speeds at specified points, and wind directions at specified points. SPLASH only computes surge heights and durations of an approaching storm.

After all the computer simulation runs are made, the outputs are compared and storms with similar impacts are grouped together. Eventually about twelve scenarios are developed which represent all the storms used in the analysis. When a hurricane threatens, the emergency manager can use estimates of hurricane intensity, speed, and tracks to classify the storm into one of the scenarios and then use the predicted surge and wind speeds to identify areas at risk. Figure 3-1 provides a sample of this hazard information. Based on the historical model validations, the data used for planning is 20% greater than the maximum storm surge depth estimated by the model. The resultant "maximum envelopes of water" (MEOWs) for each scenario define evacuation areas under each scenario.

The vulnerability analysis defines and estimates the population at risk within MEOWs. This includes permanent populations, seasonal and daily transient populations, and institutionalized populations such as schools, hospitals, nursing homes, jails, and other concentrations of people.

The behavioral analysis is done to provide data on human response to hurricane warnings. The analysis provides information on hypothetical response to different hurricane scenarios. Information is generated on when people think they would leave, how many would leave, the number of vehicles they would use, the need for public transportation, and likely destinations.

The shelter analysis identifies structures outside of MEOWs that can be used to shelter evacuees who have no place to go. Using the behavioral data the demand for shelter is estimated. Based on the estimated demand, the appropriate number and location of shelters is estimated. In addition, the availability of emergency supplies are determined and inventoried.

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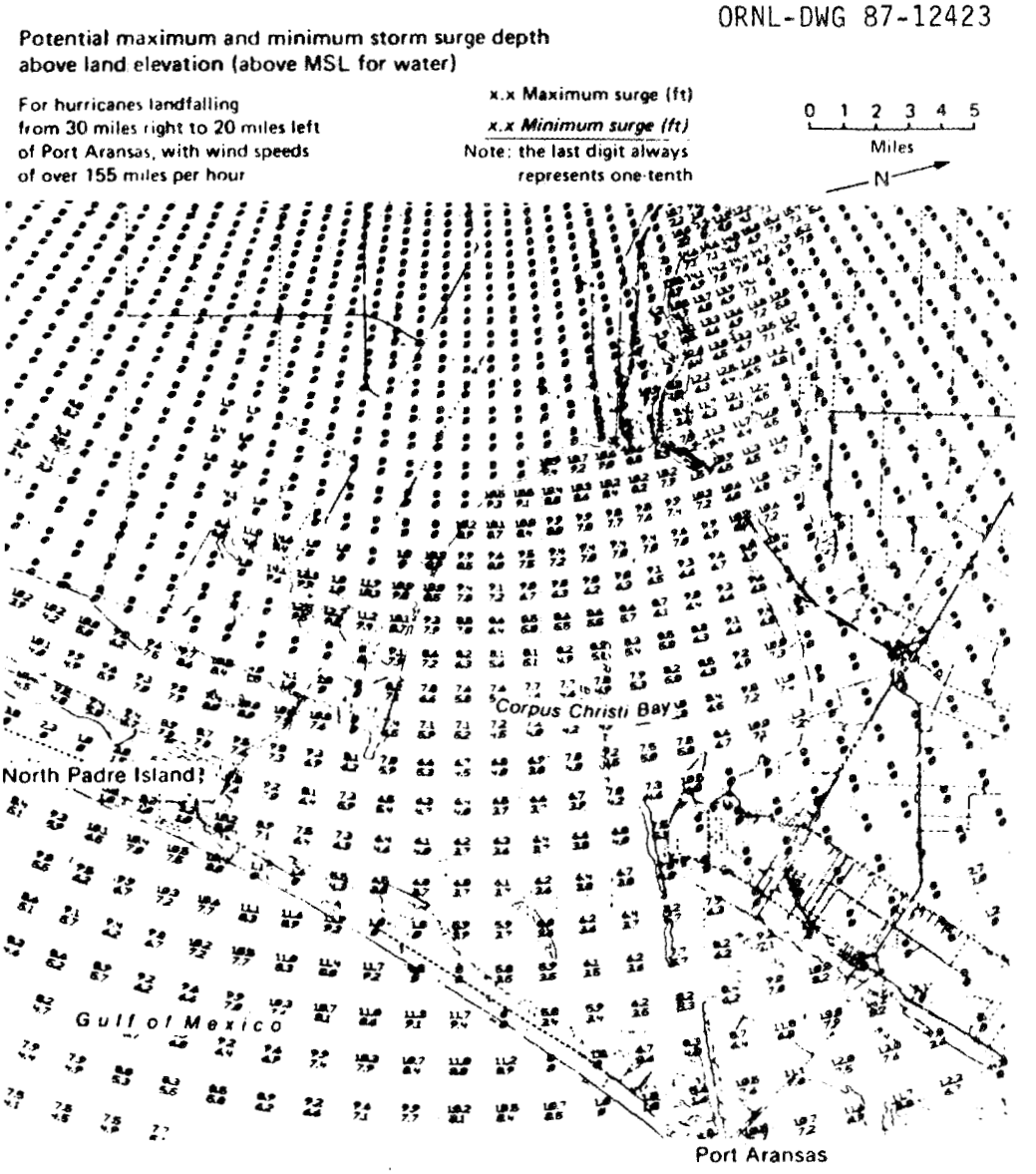

Fig. 3-1. Hurricane evacuation zone. Source: Berke and Ruch, 1985

The transportation analysis estimates the time required to evacuate various population zones. The analysis identifies evacuation routes and traffic capacities of those routes. Using data from behavioral studies, assumptions on route demand are made. Calculations are then made on how long it will take for people to evacuate into safe areas. This provides the decision maker with an estimate of when an evacuation decision should be made based on assumptions about the storm's characteristics.

Using the above technical information, evacuation implementation plans are developed at state and local levels. In support of the overall planning effort, a public information program and a property protection and hurricane hazard mitigation plan are developed as well.

3.2.2 Floods

Evacuations occur from flash and riverine floods on an annual basis in this country. No systematic records of flood evacuations are maintained to estimate how many events occur or how many people leave. In 1985, FEMA identified about 25 flood events that prompted localized evacuation (FEMA, 1986a). The largest involved 3000 people evacuating due to heavy flooding in Illinois. The Mississippi River has been the cause of many major evacuations. In 1983, an estimated 25,000 people evacuated in Louisiana prior to a major flood that left the residences of 100,000 people under water.

Evacuation is also a major protective action for flood events. Unlike for hurricanes, no national program for flood hazard evacuation planning has been established because floods are viewed as fairly localized problems. The basic approach that has been developed for use on a state and local basis is similar to that for hurricanes but is less sophisticated. The ideal approach follows five steps (Flood Loss Reduction Associates, 1984a; 1984b; 1984c):

1. analyzes the source of flooding,
2. analyzes the causes of flooding,
3. analyzes flood characteristics,
4. analyzes areas subject to inundation, and
5. analyzes areas at risk.

Sources of flood waters can include snowmelt, rainfall, dam failure, or a combination. Floods can occur from overbanking of a stream, drainage down a dry basin, or from overland flow. Floods can be caused by insufficient drainage capacity, blockage of channels by ice, encroachment of flood plains by construction, and urbanization. Floods vary as to velocity, depth, speed of onset, rate of water rise, duration, and seasonality.

The National Flood Insurance Program (NFIP) has developed inundation maps for communities on a national basis showing the locations of floodplains and floodways. Some additional investigation of risk factors, such as population at risk, building characteristics,

and flow velocities, to supplement floodplain maps may be needed by local communities to develop evacuation plans.

Once such data are established, a flood recognition system is developed to provide a lead-time for warning and evacuating populations at risk. These systems typically involve a combination of rain gauges in upstream basins to measure rainfall and automated stream height gauges to measure stream flow. By calculating run-off from precipitation data, flood stages are estimated with sufficient time for evacuating people at risk.

While this represents current philosophy many, if not most, flood evacuations are carried out on an emergency ad hoc basis, as a perceived need is recognized. The NFIP has provided most communities with inundation maps which can be used to guide evacuation activities. Most floods are of a slow enough onset to provide ample time to recognize a hazard and move people. Evacuation planning for flash floods is still problematic because of the short warning time.

3.2.3 Tsunami

Tsunamis are rare events in comparisons to floods and hurricanes. Evacuation warnings have been issued for only a few events in the past 10 years in the United States. In 1986 seismic activity in Alaska prompted an evacuation warning for Hawaii, but the event never materialized. The last major tsunami to strike the western continental coast was in 1964 following the Alaskan earthquake. In Hawaii, the most recent tsunami that resulted in fatalities occurred in 1978 on the south coast of the island of Hawaii.

Evacuation planning is needed for two types of tsunamis. Distant tsunamis originate from seismic activity across the ocean. Local tsunamis originate from seismic activity just offshore of the affected area. The Pacific Tsunami Warning System detects distant tsunamis through tide-monitoring stations. This provides between four and fifteen hours of lead-time which is generally sufficient to evacuate high risk areas. Risk areas are delineated as part of the NFIP and provide estimates of maximum run-up heights. These delineations are subject to some uncertainties because of the lack of a good historical record. In some high population areas such as Hawaii, maps and evacuation instructions are published in the telephone book. In some remote areas evacuation instructions are printed on signs and markers denote heights that are safe from the waves.

Local tsunamis present greater evacuation problems. The wave occurs within minutes of the seismic activity. An evacuation needs to occur rapidly. Currently the only means to warn of a local tsunami is through the use of sirens activated by a predetermined-magnitude earthquake. The disadvantages of such systems is that they will be accurate only 10% of the time because few offshore earthquakes result in a local tsunami.

3.2.4 Volcano

Evacuations due to volcanic activity are implemented regularly on the island of Hawaii. The last experience on the Kalapana coast area came in November, 1986, due to an eruption of Kilauea volcano. Eruptions could eventually lead to a need to evacuate Hilo, the largest town on the island. In the past 10 years, two evacuations due to increased volcanic risks took place in the continental United States. The first was at Mt. Baker, and the second at Mt. St. Helens. Both are in the state of Washington. The eruption at Mt. Baker never occurred, but the evacuation at Mt. St. Helens likely saved many lives. A third possible evacuation situation may be developing in the Mono-Inyo crater chain near the resort area of Mammoth Lake, California. Evacuation plans and routes have been developed because of increased volcanic activity, but they have not been needed to date.

Evacuation planning is therefore needed for volcanic activities in Hawaii and in the Cascades in the Pacific northwest states. Currently, no systematic approach to evacuation planning has been implemented on a national basis due to the rarity of eruptions. In Hawaii, eruptions are frequent and of a slow protracted nature. Emergency planners evacuate sparsely populated areas in the projected course of lava flows. Evacuation plans are based on numerous eruptive sequences and frequent experience with evacuation. In the Cascades, eruptions are rare events, and evacuation planning is more difficult to implement except after a threat materializes.

The basis for site-specific evacuation planning comes from the USGS geological hazard assessment program. Detailed studies are conducted to determine the kind, frequency, scale, and extent of past eruptions, and what could be predicted from these data regarding future eruptions. Hazard information has been produced regarding various volcanic risks including estimates of areas subject to lava flows, pyroclastic flows, mudflows, lateral blasts, and ashfalls (Fig. 3-2). As yet, there is no systematic program that can use these data to establish an evacuation strategy for volcanoes in the Cascades. An outline of a comprehensive planning framework is provided in Fig. 3-3 that could be used for volcanic hazards.

3.3 HUMAN INDUCED HAZARDS

3.3.1 Dam Failure

Notable dam failures have occurred in the United States where the failure to evacuate has resulted in high loss of life. A dam failure during the 1972 Black Hills, South Dakota, flood contributed to the 230 fatalities. The disaster at Buffalo Creek, West Virginia, due to the failure of a slag heap dam in 1972 was also devastating, taking 125 lives. Dam failures during flooding at Johnstown, Pennsylvania, and the Kelly Barnes Dam above Tacooa, Georgia, have also caused fatalities. It is estimated that 9,000 dams in the United States pose a significant

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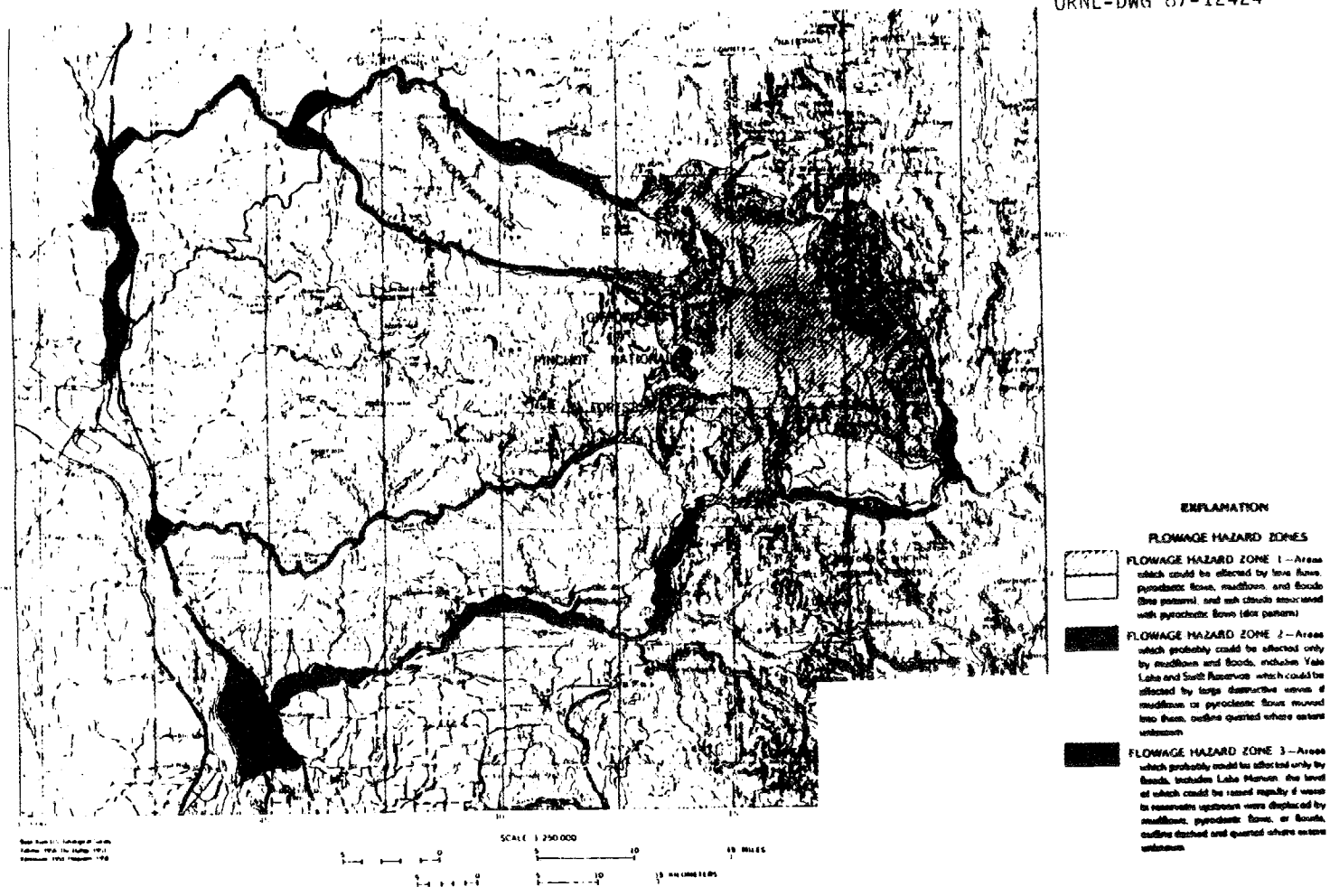

Fig. 3-2. Mount St. Helens risk zones. Source: U.S. Geological Survey.

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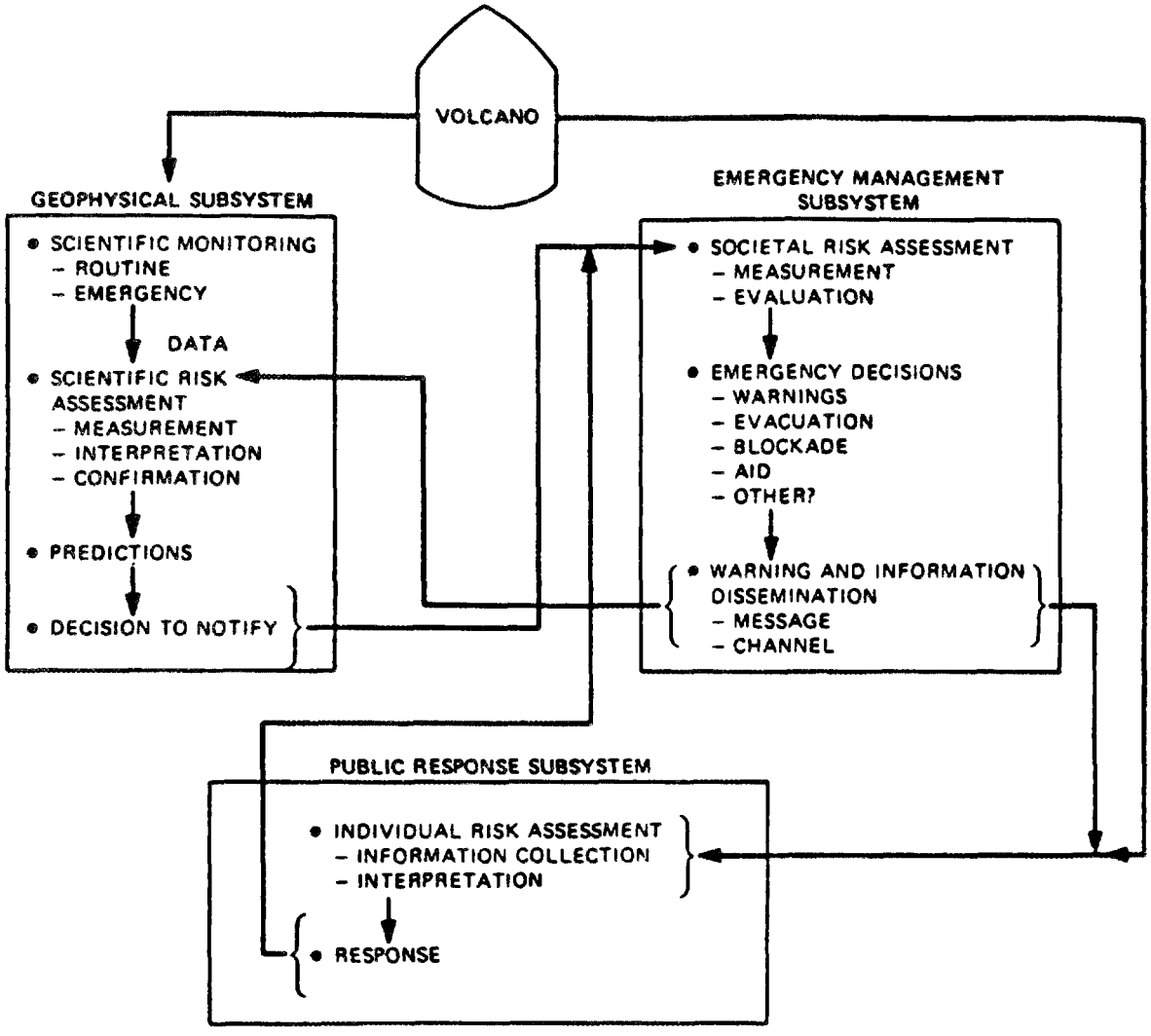

Fig. 3-3. Volcano evacuation planning framework.

risk to downstream inhabitants. From 1980 to 1985 there were about 82 dam failures in the United States, but most did not necessitate an evacuation (USFEMA, 1986b)

Evacuation planning for dams and reservoirs operated or regulated by the federal government is administered or carried out by a variety of federal agencies. The major ones include the Department of Agriculture, the Department of Army Corps of Engineers, the Department of Energy, and the Department of Interior. Federal policy for preparation of evacuation plans for dams are defined in the Federal Guidelines for Dam Safety (Interagency Committee on Dam Safety, 1979). Emergency Action Plans (EAPS) are being prepared for high- and significant-hazard dams in accordance with that guidance. The responsibility of the agencies are limited to the following actions:

1. evaluate possible modes of dam failure,
2. prepare inundation maps,
3. classify inundation areas for hazard potential,
4. assess time available for response,
5. develop planning scenarios,
6. develop a general emergency plan, and
7. develop notification plans including public warnings.

The development of an evacuation plan is delegated to the local jurisdictions at risk. These plans, according to the guidelines, may include delineation of areas to evacuate, routes, traffic control, shelters, emergency transportation provisions, needs for evacuating special or institutional populations, procedures for security and perimeter control, reentry procedures, and organizational responsibilities. Planning procedures have been developed by several agencies (USFEMA, 1986b).

Emergency planning for private dams and reservoirs is basically regulated by the states. As of 1985, 28 states had provisions for requiring evacuation plans (Tschantz, 1985). The Corps of Engineers inspects private dams that pose potential risks to the public. When an unsafe dam is identified, the Corps recommends development of an EAP. FEMA (USFEMA, 1985) has developed a general planning guide to provide assistance in developing evacuation plans.

3.3.2 Nuclear Power

Only one evacuation of the general public has occurred at a nuclear power plant in the United States. This, of course, was at the Three Mile Island power plant near Harrisburg, Pennsylvania, in 1979. This experience, involving the evacuation of about 150,000 people, is discussed in depth in the next chapter. The accident radically changed evacuation planning at nuclear power plants (USNRC, 1979b; 1981a; 1981b; USFEMA, 1980; 1982).

Two major options for population protection exist in a nuclear power plant accident: sheltering and evacuation (Gant and Schweitzer, 1984; USNRC, 1979a). Protective action planning is undertaken in a plume exposure pathway emergency planning zone (EPZ) in a radius of about ten miles (Fig. 3-4). This distance has been determined to be the likely maximum distance for harmful exposure to radionuclides although under some circumstances evacuation could be required for greater distances (USNRC & USEPA, 1978).

Protective action decisions are the responsibility of off-site government authorities; however, utilities that operate nuclear plants are required to provide recommendations. Evacuation planning requirements are specified in NUREG-0654; FEMA REP-1 (USNRC and USFEMA, 1980).

Prior to operating, a nuclear power plant must have an emergency plan approved by FEMA and the Nuclear Regulatory Commission (NRC). With respect to evacuation, the plan must include the following. First, the plan must establish a predetermined scheme for classifying an accident into one of four categories and establish initial protective actions based on the classification level. Second, means for prompt notification of the public officials and alert of the population in the EPZ must be established. Third, a means of identifying the accident source terms and projecting the atmospheric dispersion of radioactive particles must be established. These projections are used for recommending an evacuation. Fourth, evacuation routes must be identified. Fifth, evacuation time estimates must be prepared. Sixth, an evacuation implementation plan must be prepared.

The evacuation plan contains the following elements:

1. maps showing evacuation routes and areas and shelters,
2. maps of the population distribution in the EPZ,
3. the means of notifying the public,
4. the means for protecting non-mobile people,
5. projected traffic capacities of evacuation routes,
6. control of access to evacuated areas,
7. identification of and means for dealing with potential traffic impediments,
8. evacuation time estimates,
9. means of registering evacuees, and
10. mechanisms for making an evacuation decision.

The key features of this approach are that it is comprehensive, rigorous, and based on scientific studies of source terms and dispersion potentials. Several descriptions of the approach (Jaske, 1983; Olds, 1981) as well as critiques (Cutter, 1984; Hull, 1981a; 1981b; USGAO, 1984) have been written.

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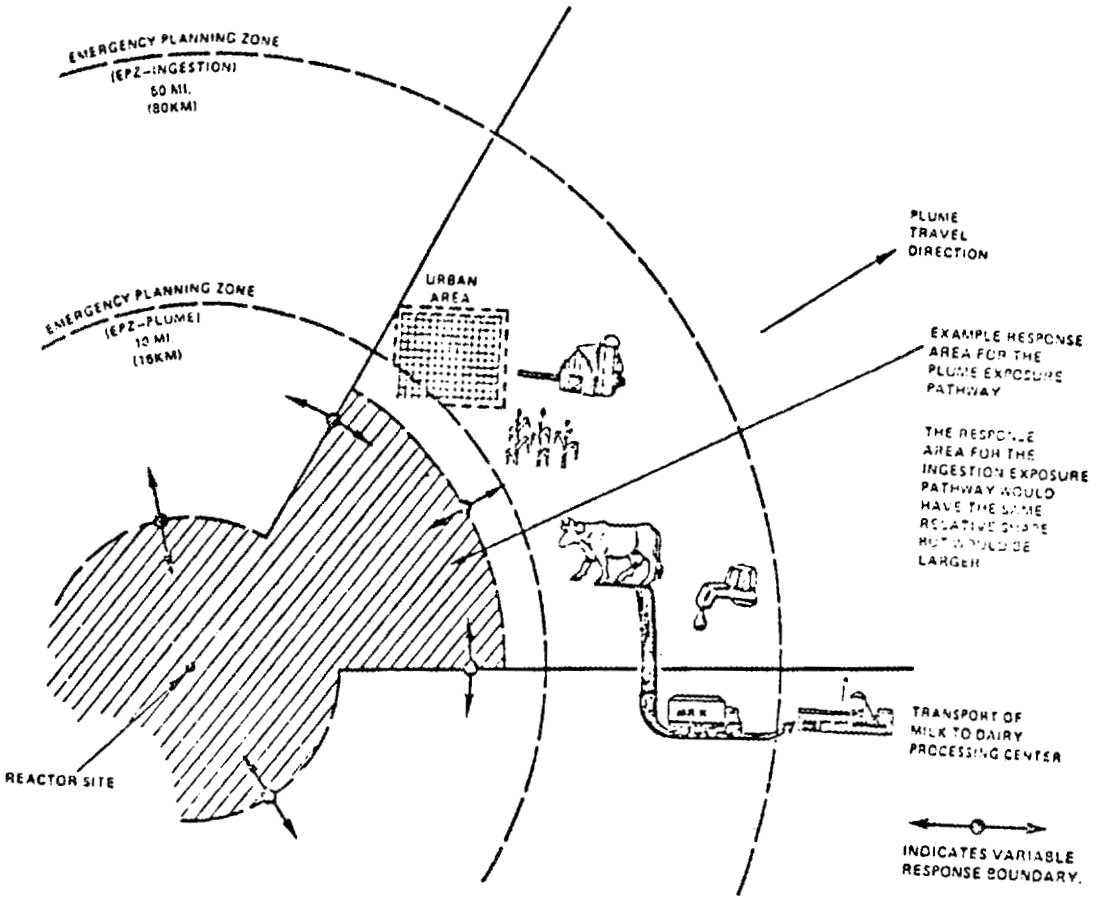

Fig. 3-4. Nuclear power plant emergency planning zone.
Source: U.S. Nuclear Regulatory Commission.

3.3.3 Hazardous Materials

There have been nearly 300 evacuations due to chemical releases in the United States during the five-year period from 1980 to 1984 (Sorensen, 1986b). Table 3-1 lists these evacuations by cause and year. These evacuations have involved the movement of about 1000 people per event on the average. The largest was estimated to include 30,000 people. In 1985, it was estimated that about 125 evacuations took place because of the release of some form of hazardous materials (USFEMA, 1986a).

Evacuation planning is done for two types of hazardous material incidents. The first is for fixed site releases of materials from production or storage facilities. The second type involves spills or accidents during transportation.

Currently evacuation planning for transportation accidents is done at a local level. The Department of Transportation (DOT) and FEMA have published guidance on developing generalized hazardous material contingency plans for transportation. FEMA publications do not provide guidance regarding evacuation planning for this hazard. DOT (USDOT, 1984) has provided some guidance on recommended evacuation distances for transportation accidents (Fig. 3-5). These do not differentiate for size of the spill (except between a spill and large spill). Other information on calculating evacuation distances is also available (Thomsen, 1984; Kelty, 1984; Sheldon, 1983).

Recent legislation, the Superfund Reauthorization Act (1986), gives some indication of the direction that federal policy is taking for fixed site hazardous materials emergency planning (USEPA, 1986). Local communities where there are facilities that store given amounts of hazardous chemicals would be required to develop an evacuation plan. It is unclear, however, how this regulation will be implemented. In anticipation of this regulation, preliminary guidance has been developed by the EPA (USEPA, 1985). This document identifies the 400-plus chemicals covered by the program but does not provide details on plan development. At the time of writing, FEMA had initiated a program that would develop more comprehensive planning guidance for hazardous materials accidents. This program is patterned after the approach used for nuclear power plant emergencies. Source terms for various accidents are being calculated and will provide the technical basis for evacuation planning. Several other planning guides are available for use in developing evacuation plans (Depol and Chercmisinoff, 1984; Terrien, 1984; Tierney, 1980).

3.3.4 Nuclear Crisis

Since the early 1960s, the government developed the idea to relocate urban populations in the face of a nuclear war (Kerr, 1983; Zuckerman, 1984). In 1984, FEMA abandoned national plans to evacuate high risk areas as a means to protect populations in an international

Table 3.1. Chemical accident evacuations by cause and year

Cause of evacuation	1980	1981	1982	1983	1984	Totals
Train derailment	14	8	13	12	8	55
Train car spill/fire	3	6	5	4	5	23
Truck accident	9	9	6	6	5	35
Truck spill/fire	1	11	4	9	7	32
Chemical plant release	5	10	15	8	5	43
Industrial plant release	3	10	18	23	24	78
Pipeline	2	1	1	0	0	4
Ship incident	2	1	0	0	0	4
Waste site accident	0	1	2	3	1	7
Other	4	5	4	0	1	14
Totals	43	62	68	65	57	295

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TABLE OF ISOLATION & EVACUATION DISTANCES

NAME OF MATERIAL SPILLING OR LEAKING (ID No.)	INITIAL ISOLATION: SPILL or LEAK FROM (drum, smaller container, or small leak from tank) ISOLATE in all Directions feet	INITIAL EVACUATION: LARGE SPILL FROM A TANK (or from many containers, drums, etc.) FIRST ISOLATE in all Directions feet	THEN EVACUATE IN A DOWNWIND DIRECTION Width miles	Length miles
Acrolein (1092)	300	620	1.5	2.4
Acrylonitrile (1093)	90	190	0.4	0.6
Ammonia, anhydrous liquefied (1005) Ammonia solution, with more than 44% (2073) Anhydrous ammonia (1005)	90	180	0.4	0.6
Boron trifluoride (1008)	320	670	1.7	2.6
Bromine (1744)	170	350	0.8	1.3
Carbon bisulfide (1131) Carbon disulfide (1131)	50	100	0.2	0.3
Chloride of phosphorus (1809)	110	230	0.5	0.6
Chlorine (1017)	140	300	0.7	1.0
Dimethylamine, anhydrous (1032)	80	170	0.4	0.6
Dimethyl sulfate (1595)	80	170	1.4	2.2
Epichlorohydrin (2023)	40	80	0.2	0.3
Ethylene imine (1185)	270	570	1.4	2.2
Ethylene oxide (1040)	80	160	0.4	0.5
Fluorine, cryogenic liquid (9192)	460	900	2.5	3.9
Hydrochloric acid, anhydrous (1050) Hydrogen chloride, anhydrous (1050) Hydrogen chloride, liquid (refrigerated) (2186)	190	450	1.0	1.4
Hydrocyanic acid (1051) Hydrogen cyanide, anhydrous (1051)	90	190	0.5	0.7
Hydrofluoric acid, anhydrous (1052) Hydrogen fluoride, anhydrous (1052)	150	300	0.7	1.1

TABLE OF ISOLATION & EVACUATION DISTANCES

NAME OF MATERIAL SPILLING OR LEAKING (ID No.)	INITIAL ISOLATION: SPILL or LEAK FROM (drum, smaller container, or small leak from tank) ISOLATE in all Directions feet	INITIAL EVACUATION: LARGE SPILL FROM A TANK (or from many containers, drums, etc.) FIRST ISOLATE in all Directions feet	THEN EVACUATE IN A DOWNWIND DIRECTION Width miles	Length miles
Hydrogen sulfide (1053)	120	240	0.6	0.9
Methylamine, anhydrous (1061) Monomethylamine, anhydrous (1061)	110	220	0.5	0.8
Methyl bromide (1062)	50	90	0.2	0.3
Methyl chloride (1063)	30	60	0.1	0.2
Methyl mercaptan (1064)	370	770	1.9	3.0
Methyl sulfate (1595)	80	170	1.4	2.2
Nitric acid, fuming (2032) Nitric acid, red fuming (2032)	100	210	0.5	0.7
Nitric oxide (1660) Nitric oxide and Nitrogen tetroxide mixture (1975)	90	180	0.4	0.6
Nitrogen dioxide (1067) Nitrogen peroxide (1067) Nitrogen tetroxide (1067)	110	220	0.5	0.8
Oleum (1831)	280	560	1.5	2.2
Perchloromethyl-mercaptan (1670)	220	450	1.1	1.6
Phosgene (1076)	600	1250	3.3	5.2
Phosphorus trichloride (1809)	110	220	0.5	0.8
Sulfur dioxide (1079)	120	250	0.6	0.9
Sulfuric acid, fuming (1831) Sulfuric anhydride (1829) Sulfur trioxide (1829)	280	560	1.5	2.2
Titanium tetrachloride (1838)	30	60	0.2	0.2
Trimethylamine, anhydrous (1083)	30	60	0.2	0.3

THIS INFORMATION IS FOR USE IN ADDITION TO THE GUIDE PAGE RECOMMENDATIONS FOR HANDLING THE TOXIC HAZARDS OF THESE MATERIALS IF THEY ARE NOT ON FIRE

Fig. 3-5. Evacuation distances for hazardous material accidents.
Source: Department of Transportation

crisis period. Crisis relocation plans are optional at state and local levels as part of the integrated planning concept (USFEMA, 1984a). In 1984, approximately 50% of the communities in the United States had done some formal planning for nuclear crisis. The current status of planning is not clear. Some communities have refused to develop plans or incorporate nuclear crises into generic plans (Schroeder, 1984).

Under the current planning process, evacuation is divided into three areas of management: command/control, analysis, and law enforcement. Command and control includes the overall coordination of the evacuation, interaction with outside jurisdictions, and logistics control. An analysis team is formed to assess the situation, to collect data on the threat, and to prepare recommendations for evacuation. Law enforcement activities include security, warning, traffic control, and evacuation assistance.

Crisis relocation planning, done at the local level, would require risk areas to develop plans based on state-level guidance regarding potential host areas. The state would also be responsible for developing a plan to support crisis relocation centers in host areas if those areas did not develop an adequate plan.

Figure 3-6 depicts the basic planning process developed by the Defense Civil Preparedness Agency (USDCPA, 1979a). The plans address the following topics: transportation of people, housing and sheltering, protection from attack, medical support, public safety, resource needs, movement of supplies, organizational relocation, and governance. A large number of planning guides have been developed to provide technical assistance to state and local governments for plan development. These cover operations planning (USFEMA, 1981; USDCPA, 1979b), public information (USDCPA, 1977), transportation (USFEMA, 1984d; Billheimer and Fratesa, 1979), and prototype plans (USDCPA, 1976; Dresch, et al., 1976).

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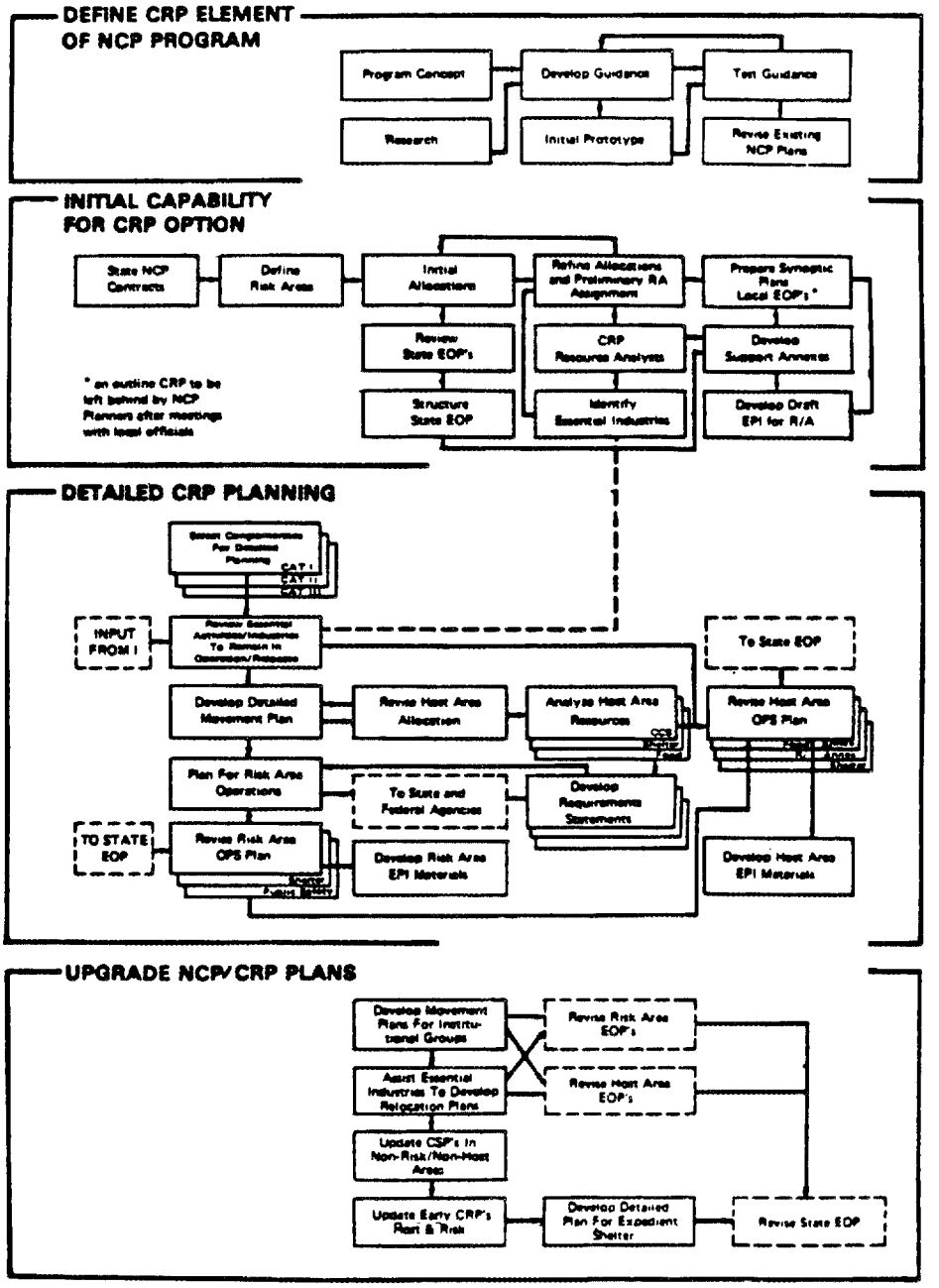

Fig. 3-6. Crisis relocation planning framework.
Source: Federal Emergency Management Agency

4. BEHAVIORAL FINDINGS

In this chapter, we review the findings of behavioral research for each hazard as they relate to evacuation issues. As Perry, Lindell, and Greene (1981) have noted, there are multiple forms of evacuation-preventive, protective, rescue, and reconstructive. Although timing and period of evacuation have been noted as methods of categorizing types of evacuation issues, we found that conceptually the boundaries were ill-defined and presented problems in separation of withdrawal patterns. The time actual evacuation begins is questionable. Should those persons who leave an area prior to any advisement by officials be considered evacuees? How do we know they did not leave for other reasons than those associated with the threat? The question arises about persons having once evacuated prior to the event who are then forced to evacuate an area a second time because of unsanitary conditions. Does this mean they evacuated the area more than once or that reentry was only temporary? Thus, the timing of evacuation appears as a continuum with various points of withdrawal instead of discrete periods such as pre-event, event or post-event definitions.

Other aspects of the literature presented a more coherent method of organization. The first aspect concerned the system level. In almost all the literature reviewed, discussions centered on either the individual or the organizational response. The second was related to information regarding source, content, and use in decision making for individuals and officials alike. How and where people received their information regarding the threat or hazard, what influenced their interpretations of the information received, what was the action taken or decision made, and finally, how did the information affect perceptions of the hazard either prior to the event, at the occurrence of the event, or experience following the event. Characteristics of the population to which a warning message is sent must also be evaluated in considering evacuation issues. Further questions raised then appeared as subcategories with focus on topics such as saliency of information given the situational context, sensitization or familiarity with hazard, life cycle variables, demographic factors and, in addition, the policy implications for planning emergency measures.

4.1 BEHAVIORAL RESEARCH FINDINGS FOR NATURAL DISASTERS

Evacuation behavior in natural disasters has been extensively studied in a variety of ways for a number of years. Studies have primarily focused on hurricane- and flood-related evacuations. The latter includes flooding from dam failures. A much smaller research base exists for other types of natural hazards. Quarantelli (1980) summarizes much of the pre-1980 literature. This report does not seek to reproduce that effort, but instead reports findings for each hazard with an emphasis on recent studies. In the following sections, the discussion begins with an

examination of behavioral issues. This is followed by an examination of the role risk and risk perception play in decision making. Research findings regarding warning and evacuation experience are reported. Each section concludes with a discussion of the implications of behavioral findings for planning.

4.1.1 Earthquakes

4.1.1.1 Behavioral issues

Two areas of research have been investigated for earthquake hazards: (1) behavior during and following a quake, and (2) behavior elicited by earthquake predictions or forecasts. Although the United States has experienced only four major earthquakes since 1900 that caused substantial damage and loss of life, scientific evidence points to one or more catastrophic earthquakes before the end of the twentieth century (Mileti, Hutton and Sorensen, 1981). Methods of predicting a destructive quake, although studied worldwide, are not conclusive. Like other hazardous threats, the risks require careful assessment of both individuals and officials.

Some areas of the United States are assumed to be more prone to earthquakes. The Panel on the Public Policy Implications of Earthquake Prediction (1975) noted that although earthquake preparedness measures have been concentrated in the Western states, the possibility of quakes in the East and Midwest should also be considered, especially in new building constructions.

4.1.1.2 Risk and risk perception

Obtaining and using information generated by earthquake predictions to determine the risk involved is riddled with problems compounded by the ambiguity and general system dynamics of earthquake prediction. By far the most extensive studies of earthquakes have been conducted in California where intensive monitoring and pseudoscientific prophecies have captured both the public's and media's interest. Both short- and long-term studies have focused on the earthquake predictions effect on residential behavior regarding the earthquake risk.

In a longitudinal study on human response to earthquake prediction at the individual level, Turner et al. (1979) found that the majority of respondents received their information from media sources such as television news broadcasts (88.5%), followed by newspapers (76.7%), and radio (70.9%). Surprisingly about half (48.8%) received their information from movies, but only 3.3% from organizations to which they belonged. Awareness of the earthquake prediction threat was not converted into more extensive preparations. In support of this finding is Kielcolt and Nigg's Los Angeles, California, study which revealed that "mediating cognitive and behavioral variables do not appreciably increase the likelihood that people living in earthquake-endangered areas and structures

will consider a move due to earthquake threat" (1982:151). Kielcolt and Nigg reason that no relationship was found between being aware of the risk and actively behaving to lessen the threat was because no community definition of a "crisis" had developed nor had any of the near-predictions disrupted the everyday "normal" life of the community in a systemic manner. According to the Kielcolt and Nigg survey data, almost three-quarters (72.8%) of the respondents had discussed the possibility of an earthquake but less than half (43.4%) thought a damaging quake would occur within the next year.

Kielcolt and Nigg (1982) found that people did not translate the objective knowledge about an earthquake hazard into decisions to move (to evacuate from the area permanently). In addition, they found that persons most fearful tended to take no actions whereas those less fearful were more likely to consider moving. The greater the perceived risk (including greater knowledge of predictions, expectations for future quakes or being a member of an endangered group), the greater the probability of moving. Contrary to Von Arsdol's 1964 findings on hazard perceptions of Los Angeles residents, ecological location seems to have little effect on the perception of the hazard. "For Los Angeles residents, objectively being "at risk" is not a sufficient reason to consider moving from one's community" (Kielcolt and Nigg, 1982:151). Rather the common mobility variables, such as life-cycle, attachment to community, owner-occupancy and socioeconomic factors, were found most influential in the decision to move from the threatened vicinity.

In terms of interpretation of earthquake predictions, the Panel on Public Policy study (1975) indicated that in general people have difficulty interpreting what is meant by a prediction and, therefore, are confused regarding response to predictions. The report also noted that the distinction between a warning and a prediction is often misinterpreted by the public. This is not surprising because both the time-window and saliency of the threat are difficult to assess given the current state of the art. Others maintain that distinctions between warnings and predictions are meaningless (Committee on Socioeconomic Effects of Earthquake Prediction, 1978).

The Turner et al. (1979) longitudinal study in Southern California found that saliency regarding earthquake hazards decreased over time but that more discriminating attention, termed "increased realism," was accorded the threat. The study also noted that changes occurred in the number of actual announcements remembered during the study. This factor was not correlated with the actual number of announcements available during the study period. In assessing the awareness of the earthquake hazard, Nigg (1982) noted a lapse of active interest in the threat, but no similar decline in personal preparedness nor decline of support for additional government preparedness planning occurred over time.

4.1.1.3 Warning experience

"Crying wolf" by authorities is not viewed as a problem if or when an earthquake threat originates. People wanted to be kept informed and looked to the government to provide accurate appraisals of the earthquake danger (Turner, 1983). Turner et al. (1979) noted the tendency of people to interpret small quakes as clues to the imminence of a destructive quake. Overall, however, earthquakes remained of low saliency even though people wanted more information than they received (Turner, 1983).

Mileti et al. (1981) documented citizen response to a pseudo-scientific prediction in Wilmington, North Carolina. More people responded to the warning than believed in it. The most frequent response was to stockpile emergency supplies. Only a small fraction of the population (two families) evacuated. Ten percent reported that they would consider moving because of the warning. Persons of lower socioeconomic class were more likely to view the warning as credible but were less likely to respond to the warning.

4.1.1.4 Evacuation experience

The Arnold et al. study (1982) examined the evacuation behavior of persons in a six-story building in California following earthquake damage. In assessing the actions, the study found that the evacuation behavior showed the force and value of emergency drills--over three-fourths (or 79%) of the evacuees followed drill procedures for bomb threats. Although no order to evacuate was given, withdrawal from the building appeared an instinctive reaction once the trembling had stopped. Entire evacuation of the building took only four to five minutes to complete. People followed paths of "leaders" or those first to evacuate. No one panicked during exiting. Most people (83%) had previous earthquake experience, and 70% of respondents based their initial response on previous experience with earthquakes including remaining in the building and sheltering until action stopped. Furthermore, instinctive daily patterns outweighed correct evacuation exiting according to earthquake drills--evacuees used the exit most familiar to them. Thus, asking evacuees to evaluate alternate routes (i.e., between bomb threat and earthquake threat) appears unrealistic in an actual emergency.

4.1.1.5 Planning issues

Mileti, Hutton, and Sorensen (1981) studied responses to earthquake prediction and found that both families' and organizations' image of damage was positively and directly related to responses to earthquake predictions. Access to information and ties to place of residence increased actions to reduce vulnerability. Overall they found that the more resources available, the greater the choices to reduce vulnerability and increase preparedness (i.e., the benefits of earthquake prediction accrue to the affluent, not the poor).

The Panel on Public Policy Implications of Earthquake Prediction (1975) observed that public mitigation measures must deal with legal and economic consequences as well as the problems of equity and political intrusions. Conflicts may result from confrontations between media and officials. The Panel (1975) suggested evacuation of specific populations-at-risk rather than general evacuations. The Panel study also cited the need for the federal government to establish guidelines for earthquake mitigation policies. Such guidelines would ensure that coordination and continuity of planning measures would not be influenced by local agendas or politics.

4.1.2 Floods

4.1.2.1 Behavioral issues

Unlike earthquakes, floods are frequently predictable and generally follow environmental cues alerting people to danger. When there is no excessive rainfall to provide cues or residents lack experience with floods, then the warning response is often met with disbelief and inaction. Generally, confirmation of the event can be obtained through official or media sources. These generalizations do not apply to flash floods or to unexpected or infrequent flooding, such as occurs in usually dry arroyos in the southwest desert regions, or to dam-failure-induced flooding.

French et al. (1983) analyzed mortality rates from 34 flash floods over a 12-year period and found that the highest number of deaths per flash flood occurred when dams failed. Of the deaths associated with flash floods, 93% were due to drowning, 42% of those deaths were car-related. Thus, using a normal behavioral means of escape--via car--can have disastrous results in flood situations (Gruntfest, 1977; Moore et al., 1982; Sorensen, 1986a). Some anecdotal evidence also suggests convergence behavior may contribute to deaths from flooding. Officials have frequently found crowd control a problem during major flooding. However, empirical evidence on the behaviors leading to flood fatalities is scarce.

4.1.2.2 Risk and risk perception

The social context in which warnings are issued plays a critical role in people's response to warnings to evacuate flood-prone areas. Perry, Lindell, and Greene (1981) conclude three major social-network variables affected warning response--kin interactions, community involvement, and age. The social-psychological variables that shaped the evacuation decision were (1) warning belief, (2) level of perceived risk, (3) possession of adaptive plan, and (4) family context in which the warning was received. Gruntfest (1977) found that those persons in groups of five or more were more likely to do something (i.e., take protective action) than were persons acting alone. Such collective decisions are credited with the increased survival rates for group

members during the flash flood that hit the Colorado Big Thompson Canyon in 1976.

4.1.2.3 Warning experience

In short-term events, situational context--whether families were together at the time of warning--and perceived warning certainty were found to have no predictive value for warning confirmation (Mileti and Beck, 1975). Mileti and Beck also found that evacuation in the Rapid City, South Dakota, flash flood seemed to be a function of warning belief, itself a function of confirmation. After receiving several warnings, mass-communicated messages were found to be a strong predictor of warning confirmation. These authors argue that evacuation could have been maximized in Rapid City had additional warnings been issued through the media broadcasts. Mileti and Beck (1975) also conclude that time may be the central variable in explaining behavior elicited by warnings in predisaster settings; and they suggest that an additive evacuation model be developed to consider the variables of time, number of warnings given in specific circumstances, and the type of disaster.

Who issues the orders affects evacuation response. Warnings delivered through personal modes by emergency workers are the most effective (Gruntfest, Downing, and White, 1978; Graham and Brown, 1983). In a study of an unexpected flood in Denver, Colorado, Drabek and Stephenson (1971) found that messages from authorities were frequently interpreted as "orders" to evacuate by residents. Moreover, 70% of the respondents recalled receiving initial warnings from authorities.

Contents of warning messages were also found to influence people's response to warnings (Mileti and Beck, 1975; Gruntfest, Downing and White, 1978; NOAA, 1981). Graham and Brown (1983) found that most people responded appropriately by evacuating after the 1982 collapse of the Lawn Lake Dam in Colorado. In this instance, convergence behavior caused the death of one individual who went to the flooding river ostensibly to observe and help. Other people were also observed running to the river to take photographs and moving only when "they saw cars floating toward them. . ." (Graham and Brown, 1983). After the disaster, criticism was directed at national park forest rangers for issuing warnings that were too "gentle."

4.1.2.4 Evacuation experience

Family context, including linkage to extended families, is very important in helping to explain evacuation response regardless of age. Young's survey data (1954) notes the social-psychological significance of keeping the family intact during an evacuation experience. Drabek and Stephenson (1971) found four evacuation processes emerged from their data: (1) evacuation by "default," (2) evacuation by "invitation," (3) evacuation by compromise of family members, and (4) evacuation by decision. Furthermore, families were found to respond as units not as

individuals. They also found that warning messages received from family and friends were three times as effective as media sources in producing adaptive behavior, although 70% of respondents had received initial warning from authorities. But Drabek and Stephenson (1971) also report that "regardless of warning source, initial reaction was one of disbelief" (pg. 194). Gruntfest, Downing and White (1978) also noted that, rather than panicking, people tended to disregard warnings that interfered with their normal activities during the Big Thompson flood. During a flash flood in Johnstown, Pennsylvania, fireman reported that people were hesitant to evacuate because no one felt the threat of flooding (USDOC, 1977). Reluctance to evacuate during that 1977 Johnstown flood resulted in 76 people being killed. The next morning the convergence of spectators gathering to view the floodwater created huge traffic jams in the downtown area of Johnstown.

Suggestions that sensitization by recent threat experience influences evacuation response have also been researched. Quarantelli (1980) has noted that experiencing a crisis may sensitize individuals to the signs that would indicate a possible recurrence of the threat. Evidence indicates this may lead to increased belief but not necessarily to actual withdrawal behavior. Graham and Brown's study of the Lawn Lake Dam Failure (1983) suggests that information about the tragic flood three years previously in nearby Big Thompson Canyon had sensitized people to heed warnings and take appropriate action. Graham and Brown (1983) also noted that motel and resort owners received oral warnings directly from officials and that most people remembered receiving more than one warning to evacuate. In the Danzig et al. study (1958) of a rumor which caused unnecessary evacuation of a recently flooded community in Connecticut, flight was confined to people who lived in an inherently dangerous area. On the other hand, the study presented evidence that some firemen had sounded sirens and knocked on doors telling people to evacuate prior to denial of the rumor. Since belief was found consistent across the population while flight was confined to those at possible risk, Danzig et al. concluded that geographical proximity to the anticipated threat was the important factor in evacuation decisions. Interestingly, the same study found that officials, acting in accordance with their assigned tasks rather than personal responsibilities, asked people to wait for verification before leaving. Some studies indicate that familiarity with the environment does not necessarily increase precautionary or appropriate responses to flooding. Studies by Gruntfest (1977) and Gruntfest, Downing, and White (1978) found that familiarity with Big Thompson Canyon did not significantly elicit appropriate actions. Long-term residents of the canyon did not believe a flood of the projected magnitude could occur, and many ignored warnings because it was not raining when they were alerted. People disregarded what appeared to be false rumors and warnings that could not be confirmed, lacked specific information, or required specific actions such as climbing rock walls (Gruntfest, 1977).

Whether demographic variables significantly impact response to flood warnings is unclear. Personality, age, sex, group context, group attitudes, and socioeconomic status were all found to affect responses to the Big Thompson flash flood (Gruntfest, Downing, and White, 1978). Yet

Danzig et al.'s (1958) analysis of evacuation behavior in the case of a rumored flood report found no relationship between education and age with either the source of attempted confirmation or the likelihood of seeking confirmation before evacuating.

In flooding disasters, statistics indicate that older people die in proportionally greater numbers than would be expected. Hutton's analysis (1976) of the Rapid City flood indicates that the elderly receive as much advance warning notice as other segments of the population but, at the point of impact, may be less likely to respond appropriately because of decreased resources. Thus, lack of resources, such as diminished physical faculties, prevent or hinder elderly individuals from exiting a hazardous situation, not the lack of warnings. Perry, Lindell, and Greene (1981) found the elderly do not constitute dependent groups which hamper evacuation efforts.

Regarding ethnicity, Perry, Lindell, and Greene (1982a) present strong evidence that groups of Mexican-Americans and blacks respond differently from Anglos and that minority groups suffer disproportionately from natural hazards such as flooding. They attribute the difference to perceived personal risk, skepticism regarding the warning message, and the perceived adaptive response. Minority citizens receive, interpret, and respond to warnings differently than major population groups. Mexican-Americans are more skeptical than Anglos about believing warning messages regardless of specificity of the message. The same message elicited different interpretation regardless of warning belief and perceived personal risk. As a result, Mexican-Americans were less likely than Anglos to evacuate.

4.1.2.5 Planning issues

Experience with ongoing threats has been linked to the development of disaster subcultures. Hannigan and Kueneman's (1978) Canadian data on anticipated flood emergencies illustrates the complexity and extensiveness of the growth of disaster subculture at the organizational level. Where flooding occurs as a seasonal hazard or remains a recurring problem or where flood mitigation measures are less effective, the saliency of flooding does not decrease. When public organizations, such as the Floodway Mitigation Project in Canada, have been effective in decreasing the threat, they have found that public concern decreased. This has important implications for future emergency planning. For example, Hannigan and Kueneman (1978) found that, although the public was generally disinterested in disaster preparedness, the respondents were split regarding the role of government in regulating building in floodplains and in extending relief to flood victims.

The concept of a flood disaster uniting a community has been advanced and generally discounted. Kutak (1938) argued early on that crisis tended to blur racial and status differentials with the community being stronger after the disaster's impact. A study by Perry and Mushkatel (1984) regarding the permanent relocation of a town consisting

entirely of minority residents suggests that a community must first have strong social networks and social identity in order to survive permanent dislocation. Kai Erickson's earlier work (1976) on the Buffalo Creek slag dam failure emphasized that the loss of networks and social structure as a result of the impact of the disaster and during the rehabilitation phase totally destroyed the community. Unlike Erickson, Clifford's study (1956) of two communities flooded by the Rio Grande River found the persistence of normal social patterns including major values resisted disturbance in the emergency situation. Important normal social interactions remained the norm in the disaster and afterwards. Clifford argues that communities characterized by emphasis on familial, traditional, and personal orientations will resist interfamily aid which will hamper coordination of emergency activities.

Whether the elderly require more attention in evacuations and during the rehabilitation phase following flooding is discussed in the literature. Poulshock and Cohen's (1975) work concerning flood victims indicates that few of the elderly evacuees (15.6%) moved initially to an evacuation center but that 88% had moved at least once during the next year, 68.2% had moved at least three times, and 31% had moved four times in the year following the flood. The study also found that some housing for the elderly had improved over the pre-flood conditions. Despite indications of chronic physical problems in more than half of the respondents, the perceived needs of the elderly were for "hard" services outside the home such as housing, increased income, and transportation, and there was relatively little need for "social services."

That most flood victims take refuge in homes of relatives rather than official centers has been known for some time (Young, 1954; Drabek and Boggs, 1968). Drabek and Stephenson (1971) found that a little over 3% of their respondents stayed in public shelters. Young (1954) examined the role of kinship in British flood evacuations and found that most evacuees preferred refuge with relatives rather than using public shelters. Kinship ties tended to weaken as distance increased however.

Lack of experience in dealing with disaster is the largest problem of local leaders in post-disaster periods (Cochrane et al., 1979). Cochrane et al. argue that flood insurance is the key to a recovery program that forestalls similar use of flood-prone lands but that the program must be mandated by some agency or institution to be effective. Such politics often interfere with the development of evacuation plans for future events. Probably one of the most effective programs to reduce flood loss has been that of New York State which has developed technical manuals with the express intent of coordinating state, local, and private sector programs regarding flood warning and evacuation planning (see Flood Loss Reduction Associates, 1984a).

4.1.3 Hurricanes

4.1.3.1 Behavioral issues

Confronting a hurricane threat is difficult at all system levels of society because many of the evacuation issues are linked to the inherent ambiguity of weather forecasting of unpredictable storms. In hurricane evacuations, this is further complicated by the time dimension which affects decision making of both individuals and emergency management personnel differently from other natural hazards. Determining the time to issue evacuation warnings imposes certain restraints on emergency management officials. Furthermore timing influences the decision-making processes differently because evacuation times to safe areas varies by predicted intensity of the storm, storm direction, and population-at-risk during time of threat. At issue is the need to provide all persons-at-risk the opportunity to evacuate. Thus, authorities must calculate the maximum evacuation time including estimations of the reaction times of residents and the travel time involved in reaching a safe shelter (Simpson, 1980). For the individual, information about the particular storm threat affects perception of personal vulnerability which in turn motivates evacuation decisions (Baker and Carter, 1984). Information about hurricane hazards as well as specific site exposure is then translated into an individual assessment of vulnerability from which critical decisions are made about protective actions.

Other temporal issues relate to the actual hurricane landfall site. The impacts from hurricane landfall predicted for low-tide differ from those at high tide or when accompanied by seasonal fluctuations. Likewise delaying or dawdling storms present ambiguous situations which may result in multiple or unnecessary evacuations, a problem that emergency managers greatly fear in view of the political repercussions. The frequent tornadoes following in the unsettled wake of hurricanes also precipitate different forms of protective actions, both at the individual and organizational levels. Ruch and Christensen's experimental studies (1981) found that 72% of the people in Galveston, Texas, feared hurricane-spawned tornadoes more than hurricanes themselves. Few communities provide for the possibility of in-place accommodation for people facing the threat of a tornado (Simpson, 1980), leaving those that do not evacuate in time without options. Furthermore, persons failing to evacuate may later complicate emergency procedures by forcing emergency personnel to devote expensive resources to rescues and/or search and recovery efforts.

High population densities in coastal barrier areas with limited access routes further exacerbate evacuation procedures and place heavy burdens on decision-making personnel. Simpson and Riehl (1981) note that massive relocation of populations under threat is problematical where existing conditions include long expanses of two-lane highways, highways subject to early flooding, constricting bridges and causeways, or residential development that doubles or triples the population on holidays or during certain seasons due to tourism.

4.1.3.2 Risk and risk perception

Judgments about the risks from a hurricane threat differ with the empirical evidence indicating that the percentage of people who evacuate when warned about a hurricane threat varies by locality. Some storms generate only a 20% evacuation rate (see Davenport, 1978) (e.g., Hurricane Carla, 1961). On the other hand, the Louisiana Department of Public Services evacuation behavioral survey (1984) found that, regionally, over 91% intended to evacuate during a hurricane emergency. Clark and Carter's (1980) findings indicate the range of actual responses resulting in evacuation are influenced by the saliency of the hurricane warning and the information contained in the warning. The ease of obtaining the information and the perceived reliability of the source are also influential factors.

For the individual deciding about what protective action to take, information about the specific storm threat affects perceptions of self-danger which then motivates evacuation decisions (Wilkenson and Ross, 1970; Baker and Carter, 1984). Information about hurricane hazards in general as well as specific site exposure is then translated into an individual assessment of vulnerability from which critical decisions are made regarding appropriate protective actions. In any area, not all persons-at-risk can be expected to leave. On the other hand, the number of people leaving voluntarily on hearing of a possible storm is also largely unknown.

Demographic and life cycle variables affect adaptive behavior to hurricane warnings. Whether one is alone, married with or without children, elderly, attached to community, or a homeowner are reflected in response patterns (Carter et al., 1983; Moore et al., 1964). Length of settlement and prior experience with benign storms also contributes to complacency regarding hurricane threats and may hamper evacuation efforts. The study of warning response at the University of Minnesota (Leik et al.; 1981; Carter et al., 1983; 1979) found that (1) single residents living alone are less likely to respond to either official or unofficial statements irrespective of their perceptions of risk and instead respond to their social contacts in considering evacuation, (2) married couples with or without children are equally likely to respond to official statements although those without children are equally likely to respond to unofficial ones as well, (3) married couples with children are much less likely to respond to social contacts and to rely more heavily on their perception of the risk of storm surge flooding, confirmation of threat, as well as additional information in deciding to evacuate, (4) couples without children and single residents are more likely to evacuate with no additional incentives, once having considered evacuation, than couples with children, (5) single residents are more likely to evacuate on the basis of prior risk perception, once having considered evacuation, than couples without children, and (6) couples with or without children are more likely to evacuate on the basis of their perception of the likelihood of flooding, once having considered evacuation than single residents.

The behavioral patterns involving preferred destinations appear consistent with other natural hazards findings. A survey by the Louisiana Department of Public Safety (1984) found the majority of potential evacuees intended to go to a friend's or relative's house or to a motel/hotel rather than to seek public shelter in the event of a hurricane threat. Only 25% of those surveyed thought they would use public shelters. The Louisiana study also found a significant discrepancy between the high degree of expected evacuation and the self-reported past evacuation experience. The study found that people with previous hurricane experience who had never evacuated were less likely to intend to evacuate in the future than those with previous evacuation experience or those who were novices to the area. Moore et al.'s (1964) finding that recent experience is the most important variable in accounting for differences in response to hurricane threats suggests people cognitively relate current threat to their known (i.e., past) experience in evacuation decisions. Both Windham et al. (1977) and Wilkinson and Ross's (1970) work support the finding. Ruch and Christenen (1981) found evidence that, for individuals with prior hurricane experience, knowledge of evacuation or other protective strategies of surrounding businesses or organizations was effective in stimulating withdrawal behavior.

In simulation exercises, Christensen and Ruch (1980) found evidence that actions of neither friends nor strangers affected an individual's response to warnings. In their experiments, public response appeared to be most effectively stimulated by a combination of hurricane-related material including testimony and information regarding the threat or fear, with fear being the most effective.

Resources, including prior defensive activities and plans, affect the type of coping actions selected (Perry and Lindell, 1980). Perry and Lindell (1980) suggested that developing the incentives of warning-confirmation centers, family-communication centers in shelters, and publicized safe areas or routes in advance of events would encourage evacuation. Publicizing evacuation routes in advance and developing warning messages for media publication are recommendations included in FEMA's guidelines. Perry and Lindell (1980) point out that successful pre-evacuation programs do not directly save lives; however, they can prevent loss of property and disruption of social networks which will aid post-impact recovery efforts.

To allow complete evacuation of areas-at-risk, emergency managers must know the minimum time required to notify the general public in order to avoid liability concerns. Hurricane watches or warnings are issued by the National Weather Service (NWS), but the ordering or advisement of evacuation is subject to individual state mandates and/or local officials' legal obligations. The NWS regional storm warnings along with calculated hurricane landfall probabilities frequently cross political boundaries, thus presenting additional problems for emergency personnel who must determine specific landfall areas. Baker (1986) found that when warnings to evacuate "split" counties, Florida officials experienced difficulty because most counties were prepared to respond only on a county-wide basis. The trend by the National Hurricane Center to limit

use of hurricane watches directly impacts local emergency plans (Pinellas County Department of Civil Emergency Services, 1986). Other problems ensue when NWS advisories (in attempting to give a detailed analysis of a storm's progress) provide information which can be interpreted by area residents and media personnel as "all-clear" signals rather then the publicizing of an erratic storm.

4.1.3.3 Warning experience

As during other threatening situations, the media plays a major role in alerting the populace and providing information for residents. However the media has been criticized about the type of information provided. During Hurricane Elena, media representatives who were present at emergency executive meetings issued premature statements even when told to wait (Pinellas County, 1986). The same Pinellas County study found that conflicting information had been given to the public about bridge or road closings and openings. Simpson and Riehl's (1981) assessment of hurricane impacts noted that the lengthy warnings from the NWS during Hurricane Audrey in 1957 were edited by media personnel to leave out specific explicit messages identifying areas that coastal residents should evacuate. The research, however, does not differentiate between viewers who watched local and those who watched national coverage of the events which could influence who gains what information. The Pinellas County Study (1986) found that hurricane warnings were not carried on all cable stations nor were they available in writing for the hearing impaired--a problem in Florida with its high percentage of older residents.

Because of storm ambiguities, the most potentially dangerous information that can be given during warnings is a specific but inaccurate landfall location. A computerized system for estimating hurricane probabilities has been introduced to diffuse the risk area (Carter, 1983). However, the use of probabilistic information is questionable. Baker (1984b) found that many of the 100 emergency professionals questioned in a survey had no clear idea of how to use the factors in making evacuation decisions or had misconceptions regarding the use of probabilities. A later study by Baker (1986) found that the computerized systems were <u>not</u> utilized by Florida officials during Hurricane Elena. Guides by USFEMA (1983, 1984b) as well as articles (see Simpson et al., 1985; Ramini, 1985) have attempted to alleviate this problem by giving emergency managers specific instructions in understandable terms. SLOSH, the acronym for the Sea, Lake and Overland Surges for Hurricane model, is a computerized model for estimating areas at risk from storm surge. Ruch (1983) has utilized the model extensively in determining threatened areas along the Texas coast. Berke and Ruch (1985) utilize a computerized system to simulate hurricane losses based on two models: exposure, as evidenced by land use patterns, and hazards, as represented by wind speed and surge patterns. The system uses a computerized-geographical information system to generate a standardized data base for the spatially oriented data. Coupled with exposure and vulnerability models and damage algorithms, the system identifies location and extent of losses as well

as hurricane-prone land. The identification of the exposed population and buildings is based on regional land development scenarios that distribute growth among census tracts based on an attractiveness rating. Again the research does not indicate the extent to which the computer models are actually utilized during an emergency, especially as lifelines including electricity and telephone lines are frequently interrupted by severe storm activity.

During Hurricane Alicia (1983), the first storm in which the NWS used probability forecasts in determining landfall, the public appeared to understand the concept of probabilities (Savage et al., 1984). However, experimental research by Baker (1984a) in Florida indicates that, except in low-threat situations, issuing probability forecasts publicly has little or no effect on the individual's decision to evacuate. Baker's study (1984a) found that the most important variable was the local officials' statement advising evacuation whether or not probability forecasts were available. Evacuation procedures may be further complicated by who should be the official warning agency. When Florida's governor called for voluntary evacuation prior to Hurricane Elena's landfall without the coordination or knowledge of Pinellas County, officials had problems in opening shelters prior to evacuee arrivals (Pinellas County Department of Civil Emergency Services, 1986). In response to the governor's advisory order, an estimated 2000 evacuees congregated outside shelters before they were opened--a situation which later restricted emergency vehicles access to the shelters.

4.1.3.4 Evacuation experience

Timing, warnings, and getting people to move out once warned are all problems faced by emergency managers at the organizational level (Baker, 1980). Assigning evacuees to designated shelters does not always work either. The Pinellas County study (1986) found overcrowding occurred in some shelters because people did not always go to assigned shelters. Another Florida study found that knowledge of hurricane terms as published by NOAA and knowledge of the location of public shelters were unassociated with evacuation decisions (Baker, 1979).

Although researchers have examined residential behavior during a hurricane threat, most analyses have been made after the threat had passed and have not included actual observation of residents' actions. It is clear that not everyone will evacuate even though they are warned, but those in the most hazardous areas will withdraw to safe areas (Baker et al., 1976). Baker and Carter (1984) used a perceived benefit/cost analysis to investigate decisions to evacuate during a hurricane threat. This study found that coastal residents use whatever information is available--faulty or correct--to determine whether or not to evacuate. Quarantelli (1980) has noted that research on evacuation experience has not been separated from the general disaster experience.

In terms of appropriate actions at the individual level, it appears that the most important information regarding hurricane hazards is the

site-specific vulnerability of one's own residence (Baker, 1979). Giving the public information such as "areas near the coast will be flooded" significantly reduces evacuation rates (Leik et al., 1981; Baker and Carter, 1984). Thus, local official warnings or advisements should be as specific as possible--naming neighborhoods or streets when practical (Baker and Carter, 1984). Although withdrawal in areas adjacent to the coast is consistently high--over a 90% evacuation rate (Baker, 1983). Non-coastal, but still flood-prone, areas are evacuated at a much lower rate. When Hurricane Eloise struck Florida in 1975, Baker et al. (1976) found that 56% of the residents evacuated the inland flood-prone area as opposed to 86% of the beach-front residents. Another empirical study by Baker (1979) reexamined four previous studies of hurricane evacuation behavior (Moore et al, 1963; Wilkinson and Ross, 1970; Baker et al., 1976; and Windham et al., 1977) and found only one commonality--the likelihood that one will evacuate increases if one's neighbors evacuate. Otherwise, findings were not consistently conclusive across the studies. No conclusions regarding the future enhancement of evacuation propensity were available from the study (Baker, 1979). The importance of social ties is affirmed by Killian's early study of Hurricane Florence. Killian found that should the majority of a neighborhood not evacuate, individual families tended to ignore orders to evacuate and "ride it out" (Killian, 1954).

The Bates et al. (1963) longitudinal research study conducted between 1951 and 1961 examined the effects of Hurricane Eloise. This study indicated several reasons why residents did not evacuate: (1) disbelief in the storm's threat, (2) conflicting and misleading media reports regarding the storm's landfall times, and (3) lack of experience with the magnitude of the storm surge. As a result of this storm, approximately 1200 people were evacuated from waters, two-thirds of which were rescued by U.S. Army or oil company helicopters. In addition, blacks suffered significantly greater impacts than Anglos--black deaths averaged 322 per 10,000 total population as opposed to 38 Anglo deaths per 10,000 total population. The study found the concept of therapeutic community as outlined by Fritz (1961) useful only in the immediate post-impact phase of recovery and not applicable to the long-range analysis of social change.

4.1.3.5 Planning issues

Evacuation policies interface with political strategies in maximizing citizen safety. Vertical evacuation or in-place shelter during hurricanes has been discussed as a means of reducing evacuation times, eliminating extensive transportation planning, or as an alternative response to a fast-moving or unpredictable storm threat. Questions about the certification of safe structures, security, liability, and the right of individual owners to refuse shelter to potential evacuees remain unanswered (Simpson, 1980). Baker (1980; 1983) cites a number of other problems affecting the use of vertical shelters. First, there is the potential for overcrowding of evacuees if the option is publicized prior to an event. Second, the possibility exists for stranding those evacuees

without essential life-support systems. Third, structures could possibly sustain roof or window damage during very severe or unusual storms causing further problems for evacuees. In three recent hurricanes, a common inadequacy was the lack of knowledge about the availability and safety of protective shelters (Committee on Natural Disasters, 1985). Baker (1980) argues that another option exists to optimize evacuation and shelter capacity. He states that "impossible evacuation situations" can be presented in the first place through the use of controlled growth policies which reduce the number of people-at-risk who need to leave an area under threat.

For planning purposes, estimation of evacuation times have not been based on actual counts of vehicles leaving an area. Other measures such as the number of personally registered vehicles or surveys to indicate intended behaviors have been used for such projections. Ruch (1981) bases his estimations for modeling evacuation times on surveys of resident's intentions to use personal vehicles (1.3 to 1.6 vehicles per household), but the assumptions used in the estimates have not been empirically tested. In technical reports using SLOSH models for estimating evacuation times in Texas coastal areas, Ruch argues that there will be a three-hour delay once the warning is instituted: one hour to issue the warnings, one hour for people to prepare to leave, and one hour to prepare monitoring systems to maximize evacuation routes. Estimations of minimum evacuation times cannot assume full utilization of roadway capacity over the entire evacuation time, anticipate the use of vehicles other than those necessary for evacuation, or make appropriate adjustments for tourists in the vicinity. Specific areas need delimitation so only those residents subject to actual threat will evacuate. Ruch's estimates are based on initial evacuation prior to penetration of the storm surge or the advent of high winds. Protective actions for tornadoes spawned by "old" hurricanes are not mentioned in preparedness planning, nor are secondary or multiple evacuations that might be necessary because of unsanitary or unsafe conditions following the initial storm's departure. Ruch (1981) does note that differentials exist between overall evacuation estimates and the actual time it may take a vehicle to move through an area, but the assumptions are unclear as to estimated times or distances involved in reaching "safe zones."

A theme running through hurricane evacuation planning is that of liability associated with the obligation of public officials to provide an opportunity for all residents to leave a threatened area (Urbanik, 1980). This concern is reflected in the conservative projections of vehicles per capita and population numbers. Other hazard research suggests families act as units in emergencies. This finding goes counter to assumptions about family units using more than one car during evacuation, especially if the evacuation is viewed as temporary (as during a hurricane threat); thus it may be unrealistic for planning purposes. In questioning people about their relocation during a hurricane emergency, researchers have not focused on (1) types of vehicles actually used; (2) whether residents traveled alone, with neighbors, or in family groups; or (3) whether or not pets were included. The estimations of evacuation rates, rather than focusing on people, appear to focus on

vehicle populations. We did find evidence that some warning messages issued by officials included suggestions that families use only one vehicle when leaving. Urbanik (1980) does suggest warning residents that 50- to 75-knot winds could precede landfall by as much as 10-20 hours. Such winds can overturn trucks, motor homes, and vehicles with trailers, and this information should be included in warnings to promote evacuation compliance. Just as people underestimate hazards due to the velocity of storm surge and floodwaters, the problems from the gusting high winds of hurricanes, especially on open roads is also underestimated.

The concept of a "disaster subculture" as a mechanism for coping with ongoing or frequently recurring hazards has occupied researchers. Work by Davenport (1978) on individual responses to hurricane warnings indicates that protective actions (such as the Galveston seawall in Texas) taken by the community at large may give residents a false sense of security and may discourage future individual evacuation efforts. Length of settlement in a hurricane-prone area also contributes to complacency regarding hurricane threats. Forrest (1979) argues that residents of New Orleans developed a disaster subculture because repeated threats and impacts were dealt with through effective community mobilization when the threat occurred. This may be overcome, in part, by implementing a hazard awareness program. Christensen and Ruch (1978) analyzed the effects of brochures and electronic media presentations on hurricane awareness and planning. Their study indicated that radio had little impact, brochures enhanced knowledge, and television increased belief in the destructiveness of hurricanes. Brochures also stimulated people to pre-plan an intended evacuation route.

Schaffer and Cook's (1972) survey after Hurricane Celia found that most middle- and upper-income residents did not evacuate from the area and that most property losses were covered by insurance (cited in Quarantelli, 1980). Schaffer and Cook question whether this attitude and experience may bias future community decisions to implement loss-preventive mechanisms. Wendall (1980) points out that the existence of responsibility is the essence of liability and that the public may come to justifiably rely on governmental actions as an established response to threat. This, in turn, may change the liability regarding hazardous threats.

At the organizational level, officials' fear of "crying wolf" is not substantiated in the behavior of the public in such situations (Savage et al., 1984; Baker and Carter, 1984; Committee on Science and Technology, 1984). People tend to blame false alarms on outsiders rather than on the local officials who issued warnings (Rayner, 1953). The Committee on Science and Technology (1984) did note that the "cry wolf" syndrome had affected decisions to issue evacuation warnings when Hurricane Alicia struck the Galveston/Houston area in 1983. Emergency decision makers are often reluctant to issue evacuation warnings if they feel that evacuees have insufficient time to evacuate (Rayner, 1953; Savage et al., 1984). Officials are less reluctant to issue an evacuation order if a previous order was successful (Treadwell, 1962). On the other hand, Forrest (1979) found that hurricane disasters may act as impetus to set in motion

new response patterns. As in the literature on other hazards, separating the evacuation experience from the overall disaster and recovery periods would facilitate the research efforts.

4.1.4 Tsunamis

4.1.4.1 Behavioral issues

The ambiguity surrounding tsunamis, or tidal waves, results in part from their geophysical uniqueness and relative infrequency. The obscurity that surrounds their origins from undersea earthquakes is coupled with their unpredictability. Not all undersea movements create the energy needed to generate a tsunami, but all have the possibility of generating a tsunami with high potential for death and destruction.

Furthermore, tsunamis seldom provide warnings, other than a drop in sea level immediately prior to wave onset, to alert residents to a potential threat. Thus residents must rely on local officials to issue warnings and to institute evacuation procedures. On the other hand, emergency officials in coastal areas that are subject to tsunami inundation are hampered by lack of direct contact with the threat. They must rely on outside frequency distant sources for information on when to issue warnings. Thus the issues of evacuation are complicated by low event frequency, high disaster potential, and lack of adequate sources for confirmation.

4.1.4.2 Risk and risk perception

Investigating a tragic earthquake and tsunami that hit the Alaskan coastline, Hass and Trainer (1974) conducted three different educational pilot programs with one control group to determine the effectiveness of the tsunami educational programs. They concluded that intensive short-term public education efforts offered little hope of reducing losses of life or property during tsunamis. They found that none of the programs had any significant effect on the resident's knowledge of tsunamis, how they felt regarding the reliability of the warning system, nor their expressed behavioral intentions when faced with a future tsunami threat. The only significant improvement was in the respondents' perceptions regarding the severity of the tsunami hazard. This improvement was noted in the two programs which utilized a direct personal contact approach and the mass media.

4.1.4.3 Warning experience

Bonk, Lachman, and Taksuoka (1960) report on the response to the sounding of sirens to alert the residents of Hilo, Hawaii, about a tsunami threat. Ninety-five percent of their sample heard the siren, but interpretations of what the siren represented varied. Only 32% evacuated their homes immediately, 45% waited for further information including

waiting for another warning. Forty-four percent continued their normal activities. Fourteen people reported that they were "sightseeing" at the time of wave impact (the third and most destructive wave struck Hilo at 1:05 a.m.). Of the 197 people who did not evacuate, 57% were pinned inside wreckage and 25% were injured.

Ethnicity appeared to affect the behavioral response to the sounding of sirens in Hilo (Bonk, Lachman and Taksuoka,1960). Of the 34 non-English-speaking persons interviewed, only 21% evacuated; whereas, twice that amount or 42% of those who spoke English evacuated. In addition, formal education was not significant in distinguishing among behaviors (Lachman, Taksuoka, and Bonk, 1961).

Residents of coastal areas may associate earthquake movements with the risk of a tsunami. Haas and Trainer (1974) found that over half of the residents (58%) who were surveyed after the Sitka, Alaska, tsunami had thought of the possibility of a tsunami after feeling the earthquake. Eighteen percent learned of the threat from the radio, 14% learned of the threat through face-to-face contact, but only 2% were alerted by loud-speakers on cruising police cars. After learning of the possibility of the tsunami, 23% immediately evacuated, 26% continued their normal routine. The remaining respondents waited for additional information, sought to contact family members or began to prepare to leave. Eighty-two percent reported that they did not check on the accuracy of the initial warning. About half the respondents recalled a verbal message calling for immediate evacuation, but only 50% remembered that safe areas were identified in the warning message. A few respondents could recall that other types of basic information were given in the warnings.

Yutzy's (1964) work describes the behavior of organizations in Crescent City, California, following notification of a possible tsunami due to the Alaskan earthquake (see Weller, 1967). No formal evacuation order was issued until after the third wave had hit the city. The result was 11 deaths and devastation of 29 city blocks. Officials credited the reluctance to issue evacuation orders to limited, ambiguous, and contradictory information on passage of the wave. Yutzy suggests less tangible factors, such as prior repercussions and ridicule created from issuing alarms that proved false, may have been critical in delaying prompt action.

4.1.4.4 Evacuation experience

In the Haas and Trainer (1974) survey of the Sitka tsunami, two-thirds of those who evacuated when warned took time to collect items such as pets, bedding, clothing, water, and personal possessions. Of those evacuating, 61% went directly to their destination and stayed there until an all-clear message was received. The remaining evacuees engaged in actions such as leaving from some other place but stopping by home before finally evacuating, leaving a safe place to check on relatives, or returning home and then going back to a safe place. About half of the evacuees indicated one or more things they would do differently the next

time a tsunami warning is issued. Intention to act faster was reported by 66% of evacuees.

Comparison of actual behavior to "what would you do" question previously asked in pilot studies indicated that fewer Sitkans took time to collect items they said they would take and that separated families did attempt to contact each other as had been previously predicted by intentions. Eight-two percent of those evacuating were family units, of which half were separated at some time before the evacuation was completed.

4.1.4.5 Planning issues

In examining two communities that had experienced a tsunami (one in the Hawaiian islands and the other on the Californian coast), Anderson (1966; 1969) found that fear of public repercussions and past experience with false alarms contributed to the reluctance to issue warnings in Crescent City. Anderson found that calling for an evacuation once an actual tsunami had materialized was easier and resulted in more cooperative response to warnings. The two communities, however, differed in their reactions to the tsunami event. The island community of Hilo, Hawaii, initiated a comprehensive review of emergency preparedness plans. They enlisted the aid of the scientific community and developed written plans that included the sounding of public sirens and a 24-hour radio broadcast system to which citizens could turn in times of threat. The California community, Crescent City, did not seek scientific feedback and made no changes in their warning system which relied on personal modes of issuing warnings to residents.

To reduce future tsunami losses, Bonk et al. (1960) recommended improved public education programs regarding the hazards of tsunamis, delineation of danger zones subject to tsunami inundation, and adoption of emergency vehicles to evacuate those not capable of leaving on their own initiative. They further stress that the public must be continuously reminded of the meaning of sirens and the appropriate behavior once the siren is sounded. The ambiguous messages given through the media channels during the emergency pointed out the need for centralized information sources and warnings that are given in several languages when needed. After reviewing Crescent City's action--ordering a warning to evacuate only after the third tidal wave had hit the city, Yutzy (1964) notes, "Implementation (of a warning to evacuate) does not occur in a social vacuum but in context of past, present and future social relationships."

4.1.5 Volcano Findings

4.1.5.1 Behavioral issues

Although active volcanoes are found throughout the world with some of the most famous ones located in the Hawaiian Islands, the American public had virtually no direct experience with hazardous volcanic threats until the Mount St. Helens eruption of 1980. Consequently, most of the recent research has centered on various behaviors elicited in response to this May, 1980, eruption. A major behavioral factor associated with the Mount St. Helens' disaster was the absence of belief of the scientific predictions that such an event would occur.

4.1.5.2 Risk and risk perception

Greene, Perry, and Lindell (1981) examined how perceived personal risk, warning belief, sources of information and individual adaptive plans influenced citizens' willingness to evacuate from the vicinity of the Mount St. Helens volcano following the early detection of seismic activity. The hazard posed by the possibility of an eruption appeared variable and was not fully appreciated until after the first major eruption (see also Perry and Greene, 1983). Environmental cues such as tremors promoted warning belief, but residents made no attempt to protect themselves other than preparing to evacuate (Perry and Greene, 1983). When awareness of the risk did increase, people had difficulty identifying specific threats of volcanism, relating instead to threats with which they were familiar (i.e., floods and mudslides).

Perry and Greene (1982a) explored the effect of information on perceived risk. Prior to the eruption of Mount St. Helens, high levels of perceived threat could be attributed to the frequency of receipt of information and to confidence that the information received was credible (Greene et al., 1981). Using data from three sites at varying distances from the volcano, Perry and Greene (1982a) found relatively uniform perception of threat, frequency and sources of information, and level of confidence regarding protective actions. They note that only 10% of the sample reported hearing information about the volcano as infrequently as once a day. Mass media dominated as primary sources of information with 95% of respondents mentioning TV, 81% citing newspapers and 87% naming radio. In contrast, only 70% reported getting information from friends and relatives, while 21% received information through direct contact with state, local, or county officials. Perry and Greene (1982a) suggest the results indicate a "vigilant dominant decision pattern" consistent with the Janis/Mann decision-making model. Furthermore, the high level of perceived risk indicated that residents considered the consequences serious if an eruption took place. Sorensen's research (1981) shows that residents were unwilling, however, to give the volcano a 100% chance of erupting.

Spatial patterns were examined as factors influencing the perception of risk. Close proximity to the volcanic threat increased stress levels

at Mount St. Helens but sensitized residents did not seriously consider evacuating permanently from the mountain (Leik et al., 1982; Greene et al., 1981). Denial actions relating to volcanic risk were found in studies of Hawaiian residents who live on volcanic slopes and who associate eruptions with unmet demands from a deity named Pele. Regardless of ethnic group, offerings were made to the volcanic goddess Pele in an openly acknowledged belief in Pele's existence (Lachman and Bonk, 1960). Lachman and Bonk did a study of residents' behavior during the 1960 eruption that caused the evacuation of 250 people from the small town of Kapoha, Hawaii. The study suggests that "security-seeking" behavior is unrelated to age, ethnicity, creed, or educational attainment.

Controversy exists over the effect of ethnicity on behavioral response to volcanic threats (Hodge et al., 1979; Lachman and Bonk, 1960). Hodge et al. (1979) found that decisions varied with ethnic group as to fatalism and belief in governmental actions. People living in the Cascades preferred individual coping strategies rather than relying on governmental actions, a behavior not feasible with the current legal restrictions concerning public safety on federal lands. After examining attitudes of both residents in Hawaii and the Cascades, Hodge et al. (1979) suggest that ethnicity affects response and that experience and/or age results in skepticism about volcanic threat. Furthermore, evidence of transference of threat by individuals to other areas of risk in the Cascades appears unlikely, although geologists consider Mt. Baker an active volcano and some areas were closed as precautionary measures.

4.1.5.3 Warning experience

Examining the normative functioning of the volcano warning system on the island of Hawaii, Sorensen and Gersmehl (1980) found that strong social and community networks existing among residents living under the active threat of volcanoes have contributed substantially to the effectiveness of warning systems. They found that experience with the hazard and credibility of key personnel with knowledge of the social structure, rather than organizational infrastructure, play key roles in the management of evacuations. Other aspects, such as an off-limits emergency operations center, reduce confusion and conflict in giving out warnings.

4.1.5.4 Evacuation experience

Perry and Green's (1983) data support the argument that as actual level of personal risk increases so does the likelihood of evacuation. Data from six communities within a 40-mile radius of the mountain showed that dissemination of information was generally through media sources. They found evacuees' destinations and modes of transportation support previous findings on other hazards. Primary destinations were the homes of kin or friends with most evacuees using a family vehicle (Perry and Greene, 1983). In the Toutle/Silverlake area of Washington where almost 88% of respondents evacuated, they found about 46% of respondents going

to homes of kin, about 30% going to friends with 95% using the family vehicle for transportation. In the Woodland area where slightly under 17% evacuated, 80% (or 12 of the 15 families questioned) reported they were called by a friend or relative offering shelter to which they subsequently evacuated. When warning belief was high, 46% evacuated compared to 22% when warning belief was low or moderate. Perry and Greene (1983) note that "when risk is perceived as low, virtually no one made preparations to evacuate," but protective actions were undertaken by half of those who perceived the risk as low. They further note that when personal risk was perceived as high no matter what the level of warning belief, almost all respondents made preparations to evacuate.

Environmental cues were strong predictors of evacuation. In the Toutle/Silverlake area, residents seeing the eruption accounted for 29% of evacuees. Just over 26% left after officials urged departure, and another 20% left when urged to do so by relatives. The high level of warning belief can also be attributed to environmental cues. Thirty-four percent made no attempt to confirm warning messages. Of those who did not confirm warnings, about 77% rated warning belief as high and about 16% as moderate. Perry and Green (1983) assert that findings from both studies show that personal risk bears a strong positive relationship to warning response because when the effects of risk are controlled, the magnitude of the relationship between belief and response declines.

Leik et al. (1982) have examined levels of individual and family stress due to the Mount St. Helens eruptions. Similar to conclusions regarding mobility of families living near earthquake hazards, the Leik et al. data indicate that few families interviewed evacuated and almost none considered moving away from the volcano's threat. Although residents intend to continue to live in the area, they remain apprehensive about the volcano's activities. However, stress levels and coping behaviors change consistently, given the distance gradient from the volcano. In further analysis of stress levels, the Leik et al. study looked at caseloads at mental health clinics and hospital rooms. Although caseloads did not increase at clinics after the eruption, the number of emergency room visits greatly increased following the major eruption. Leik et al. argue the public mental clinics are not geared to viewing stress as a collective problem and, therefore, cannot handle the stress problems associated with the volcanic threat through the usual health emergency structures.

4.1.5.5 Planning issues

At the organizational level, perception of risk prior to the eruption did not differ significantly from the public's perception (Sorensen, 1981; Saarinen and Sell, 1985). Saarinen and Sell (1985) interviewed 130 officials to determine their response to warnings about volcanic hazards. Mitigative measures taken during planning for the disaster indicated that adequate flows of information about the hazard existed, but most people including officials remained unconvinced that the volcano would erupt and did not evacuate. Saarinen and Sell (1985) found a "volcanic community"

had developed of people brought together by the shared experiences during the volcanic emergency. Both Washington state DES and FEMA were criticized for their weak role in the emergency.

The media, especially the national newscasts, were criticized heavily for their handling of the emergency situation and for interfering with organizational responses. Foxworthy and Hill (1982) discuss the problems the USGS had with keeping official reports from being distorted when interpreted by the media. Attempts by media personnel to illegally enter restricted or controlled areas also were documented. Foxworthy and Hill (1982) note that among those killed at the May 18 eruption were two reporters. Sorensen (1981) found that rumors were only a minor problem, but the media's penchant for news was a major problem for responsible agencies such as the USFS or the USGS.

Sorensen (1981) found that most state and local agencies were poorly prepared for the Mount St. Helens eruption even though evidence from the USGS had indicated an eruption was probable before the end of the century. Local officials' efforts to deal with the volcanic threat were hampered by lack of definitive and understandable information and agenda regarding volcanic risks and threats. As the eruptions progressed, organizations became more adept at handling the effects. The U. S. Forest Service (USFS), an agency noted for its extensive management of forest fires, facilitated a strong response to the impending eruption mainly because of its past experience.

Foxworthy and Hill's (1982) chronological account of the 100-day period prior to the May 18, 1980, catastrophic eruption of Mount St. Helens reveals the unique network features of the organizations faced with the volcanic threat. The study accentuates the interface between the scientific community and the various agencies responsible for protecting the public. The credibility and reliability of key actors within the USFS and the USGS provided local officials with enough support to enforce closures of volcanic areas even when ambiguity existed over the exact timing or magnitude of an eruption. As a result, fewer people were in the area of risk at the time of the major eruption.

A primary problem was deciding which agency was responsible for directing emergency operations, given a volcano threat. Frequently, the political process interferes with emergency management as happened in Washington state. The Hodge et al. (1979) study comparing management of volcanism in Hawaii and the Cascades noted that neither community had built-in operating procedures for coping with threats by organizations responsible for land management. Hodge et al. suggest that volcanic hazards should be viewed as ongoing community problems with educational programs designed to elicit support when evacuation or closure is necessary. They argue this would increase tolerance regarding the ambiguity of the potential threat when officials order future evacuations as precautionary measures. The lack of a state agency responsible for issuing warnings and coordinating responses to volcanic threat was a common theme at Mount St. Helens. Had the volcano not been under the jurisdiction of the USFS and their cooperation with the USGS not as cordial, the

coordination of activities to adequately warn and keep the public from the risk area might have been impossible. Saarinen and Sell (1985) point out the unique problems encountered with such hazards as Mount St. Helens or Three Mile Island and suggest a need for nationally organized networks of experts and field staff for assessing actual impacts and problems in local areas. The roles of federal and state officials and FEMA would be better defined and thereby understood.

4.2 BEHAVIORAL RESEARCH FINDINGS FOR HUMAN-INDUCED EMERGENCIES

The range of experience with human-induced hazards is much less than for natural hazards. This is likely due to the recency with which technological hazards have begun to create serious emergencies. Consequently, the number of studies that have been conducted on evacuation for this class of events is somewhat smaller than for natural events. We will, therefore, examine the findings in more depth.

One controversy regarding evacuation behavior concerns the similarity of behavior in natural and technological events. Some researchers maintain that evacuation behavior in response to events such as nuclear power emergencies is quite different than to natural disasters (Johnson, 1983; Ziegler and Johnson, 1984). Others maintain response patterns are quite similar (Stallings, 1984; Sorensen and Richardson, 1984). Perry (1983) suggests nuclear-power-related evacuations differ in that the threat is unfamiliar, that conflicting information is more probable, and that risks are correlated with distance from source. Growing evidence suggests that while evacuation behavior may differ with respect to the peculiarities of the event, the basic social process of evacuation is similar despite the hazard agent.

4.2.1 Nuclear Power Accidents

Evacuation behavior has been extensively studied at the one nuclear power plant accident that involved evacuation. The 1979 accident at Three Mile Island (TMI) nuclear power plant, Middletown, Pennsylvania, caused approximately 145,000 people within a 15-mile radius to evacuate. As many as 170,00 in the vicinity are estimated to have evacuated. The evacuee behavior is well documented and explained by the studies conducted following the incident. In addition, evacuation behavior has been studied using behavioral-intent-type surveys. Because these research findings concern only one nuclear power plant accident, the extent to which they are generalizable will also be discussed.

4.2.1.1 Evacuation studies of TMI

Results from three major surveys have been published concerning evacuation behavior at TMI. These include the "Michigan State Survey" (Ziegler et al., 1981), the "Rutgers Survey" (Cutter and Barnes, 1982), and the "NRC Survey" (Flynn, 1979). The latter has been used by others

to analyze evacuation behavior in more depth (Houts et al., 1984; Sorensen and Richardson, 1984). Surveys by Bartlett et al. (1983) have replicated the NRC surveys in addition to expanding the data base. Other surveys have been conducted regarding the TMI accident and have incidentally included evacuation in their findings (Goldsteen and Schorr, 1982).

Flynn's study was conducted for the U.S. Nuclear Regulatory Commission (NRC). Its chief limitation is the five-month period of time that elapsed between the accident and data collection. Questioning was retrospective, and intervening factors may have biased the results. The study focused on approximately 1,500 households sampled by random-digit dialing. The quota sample was stratified by distance from the plant with decreasing probability of selection. Because data were collected by telephone survey, families without telephones are not represented by the sample. An overall response rate of 75% is estimated.

The Flynn study is implicitly guided by a type of social impact assessment framework. This is reflected in the questionnaire design and presentation of results, which is exclusively descriptive. No attempt is made to explain evacuation behavior which is discussed in detail. The study contains a wealth of descriptive information about the effects of the accident on the local population.

The Michigan State study (Ziegler et al., 1981; Brunn et al., 1979), conducted shortly after the event, suffers primarily because of the accompanying inadequate research design. The methods section of the study suggests a random sampling procedure whereby respondents within 15 miles of TMI were selected. The sample was drawn from community phone books. Two communities beyond 15 miles of TMI served to stratify the sample for distance but are not representative of a more distant population and are not treated as control groups. Of 300 questionnaires mailed, 150 were returned for a response rate of 50%. This poor response rate and small size of the mailing limit the ability to examine behavior in terms of geographical effects, and the non-random sample impedes generalization of findings to a larger population.

The theoretical basis of the Michigan State study is again largely implicit and a posteriori. The authors use a stress model to describe evacuation behavior. Although it is largely void of psychological research on stress, it provides a reasonable and interesting hypothesis about the cause of evacuation behavior. The results of the study, however, are descriptive, and no statistical criterion is used to accept or reject the stress model suggested by the authors.

Cutter and Barnes (1982) use a random sample of 1000 households for a mail survey. Fifty households were drawn from 20 five-mile quadrants surrounding TMI using addresses from phone books. A total of 359 responses were received, yielding a response rate of 35.9%. The authors made no attempt to increase the response rate, to determine the cause of non-response, or to determine the representiveness of the sample. The self-selected sample should not be considered representative of the population around TMI. This makes generalization to the entire population at

TMI suspect which is unfortunate, given the study intent of portraying the social correlates of evacuation.

Again the model used to frame the research in the Cutter and Barnes study is largely implicit. The main strength of the study is that the framework appears to be derived from other empirical studies of response to disaster. Evacuation behavior is analyzed with several social characteristics and distance. Findings are based on chi-square tests of association. Results are well integrated with other disaster research findings.

A major problem of all three studies is their theoretical approach. None used an explicitly defined model to guide the analysis or test hypotheses. Only Cutter and Barnes linked their findings to a model that has more general applications. Ziegler et al. attempt to derive a theory from their study but fail to provide tentative support or refutation on empirical grounds for that theory. Flynn provides data which could be used for a more scientific approach, but it is not pursued. The thrust of all three reports was to describe how many people left for what destination rather than to gain an understanding of why people did so.

Of the three, only Flynn has an adequate sample to permit generalization to the TMI vicinity, although not without bias. Both the Cutter and Barnes study, and the Ziegler et al. study incorporate methodological problems which make any generalizations to the total population severely suspect. Of the three studies, only Cutter and Barnes have attempted to scientifically analyze the relationship between evacuation and explanatory factors. More robust and sophisticated techniques than those utilized would have strengthened their analysis. Even so, analysis is a posteriori and not guided by a theory.

4.2.1.2 Evacuation behavior at TMI

From the studies, we gain a good descriptive account of the evacuation. About 39% of the population within 15 miles of the plant evacuated. A small number of people evacuated at greater distances as well. Evacuation rates declined with distance and varied with respect to direction from the plant (Flynn, 1982). Within 5 miles an estimated 50 to 60% left (Flynn, 1979). Those who left stayed away a average of five days and traveled a median distance of 85 to 100 miles. Most evacuees went to friends and relatives (78%) or motels (15%). Flynn (1979) found that a few people used official shelters, whereas Ziegler et el. (1981) found that no one in the sample they interviewed used official shelters. Evacuation rates decreased as distance from the plant increased. Ziegler et al. (1981) also observed that as distance increased evacuees travelled longer distances but stayed away for a shorter time. The number of people who left and their destinations are thought to have been influenced by the time of the accident which enabled people to leave for the weekend (Smith, 1979)--the first nice weekend of the spring season.

Demographic characteristics of evacuees are well documented. Families with children were more likely to leave (Cutter and Barnes, 1982) particularly if the children were pre-school (Sorensen and Richardson, 1984). Seventy-one percent of the pregnant women evacuated (Flynn, 1979). Single-member households were less likely to evacuate (Cutter and Barnes, 1982). Older people were less likely to evacuate (Cutter and Barnes, 1982; Smith, 1979; Sorensen and Richardson, 1984). Evacuation was not associated with educational levels in any consistent way (Cutter and Barnes, 1982). People with neighbors who evacuated were more likely to evacuate (Cutter and Barnes, 1982) while those who knew a worker at the plant were less likely to leave (Sorensen and Richardson, 1984).

4.2.1.3 Risk and risk perception

People who evacuated were less satisfied with information being provided and perceived a greater threat to their safety (Sorensen and Richardson, 1984). Stated differently, evacuees felt more susceptible to damage from radiation and were more upset and threatened than non--evacuees (Houts et al., 1984). People left because they were concerned with safety (Ziegler et al., 1981), perceived danger (Flynn, 1979), heard conflicting information (Ziegler et al., 1981; Flynn, 1979), or wanted to avoid a forced evacuation (Flynn, 1979). People stayed because of conflicting information (Ziegler et al., 1981), an absence of clear and credible information (Lindell and Perry, 1983) there was no danger (Ziegler et al., 1981), they were waiting for an order (Flynn, 1979), or because no order was given (Ziegler et al., 1981). People perceived that the utility company was not a useful source of information and evacuated because of a lack of trust in that information. People, however, did not equate the lack of credibility of the utility as an organization with that of technical or scientific people within the utility or nuclear industry (Sorensen, 1984b).

4.2.1.4 Behavioral intent research

A telephone survey of 2595 people on Long Island was conducted to evaluate evacuation intentions of households who were given three brief hypothetical scenarios of nuclear power plant accidents (Johnson, 1984; Johnson and Ziegler, 1984a; 1984b; Ziegler and Johnson, 1984). These scenarios included a 5-mile sheltering recommendation, a 5-mile selective evacuation of pregnant women and children, and a 10-mile sheltering recommendation, and a 10-mile total evacuation. The authors' interpretation of the results of the survey was that many people who were not advised to evacuate will do so if an emergency occurs. In fact, people 50 miles away from the TMI site expressed an intention to leave. However, level of intent to evacuate, should a similar event occur, decreases with distance from the site.

Analysis of the data suggests that those who would comply with recommendations in the scenarios were younger people who were concerned

with nuclear risks. People who expressed an intent to go beyond the recommended action and who would evacuate were middle aged, perceived greater dangers, and lived farther away from the plant site. Those who intended not to take protective actions were older, perceived less danger from the nuclear power plant, and lived closer to the plant site.

The authors conclude from this study that evacuation in another nuclear plant emergency will resemble that at TMI. They label this phenomena of "over response" the "evacuation shadow phenomena." Several problems, however, rest with this logic. First, the scenarios do not resemble the type of information people would actually receive in an emergency. Thus, the survey measures response to an unrealistic situation. Second, a careful analysis of the survey questions suggests that respondents are led, or predisposed to respond with an evacuation intent. Third, the response categories offered respondents are incomplete and not mutually exclusive. Overall, the results of this survey approach should be treated cautiously in accord with its shortcomings.

4.2.1.5 Planning issues

Despite the high investment of research dollars and labor into the question of effects of the Three Mile Island incident, only two works have looked systematically at organizational behavior in an analytical way. Neither of these efforts, however, were actual scientific investigations. Nevertheless, both the work of the President's Commission on the Accident at Three Mile Island (Dynes et al., 1979) and that of the Special Inquiry Group of the Nuclear Regulatory Commission (no date) provide some conclusions and evidence as to what had an effect on organizational behavior, coordination, and effectiveness during the Three Mile Island incident. Summary statements of these observations follow. They fall into five general categories: (1) domain consensus and role specification, (2) communication, (3) planning, (4) funding, and (5) coordination.

(1) **Domain consensus and role specification.** A repeated set of conclusions voiced by those who investigated the behavior of organizations in the Three Mile Island incident concerned domain assumptions; who should do what, when they should do it, who was in charge, how things should get decided, none of which was clearly delineated. For example, a major conclusion of the Special Inquiry Groups of the Nuclear Regulatory Commission (no date) was that ". . . there was no effective, coordinated emergency response plan in the operational mechanism and responsibilities of interagency response coordination and command were clearly spelled out" (p. 1007). The President's Commission on the Accident at Three Mile Island (Dynes et al., 1979) made a series of observations that support the conclusion that domain consensus and role specification were weak. It was noted that problems were created by multiple jurisdictions in terms of knowing who should do what. Federal and state officials disagreed about the nature of the information on which to base evacuation decisions and other protective action decisions during the emergency. Other examples mentioned that local and county governments had the

primary action role from the point of view of other organizations. Yet no local community had assumed this role nor did any have an emergency response plan. Furthermore, the role of the Commissioners of the Nuclear Regulatory Commission and the specification of their decision-making process during the accident were ill-defined. The conclusion seems straightforward in that the lack of specification of jobs and consensus about tasks among organizations hampered the coordination of organizational response to the incident and lessened the effectiveness of response.

(2) **Communication.** Another conclusion of these two inquiry groups was that interorganizational coordination and effectiveness were reduced because of poor interorganizational information flow or, in other words, poor coordination. The Special Inquiry Group of the Nuclear Regulatory Commission (no date) found that the lack of a liaison person in the State Health Department constrained communication and deflated effectiveness. Effectiveness also suffered because the telephone communication system used by organizations was overtaxed and eventually broke down. The President's Commission on the Accident at Three Mile Island (Dynes et al., 1979) also pointed to communication as a cause of lessened interorganizational coordination and effectiveness. For example, the effectiveness of the Pennsylvania Emergency Management Agency (PEMA) was lessened when the Director of PEMA was excluded from interorganizational meetings. The President's Commission also pointed out that communication between the Nuclear Regulatory Commission (NRC) and the management of the utility was poor and that the NRC was not able to get a clear picture of the actual on-site conditions. From these and other observations, it seems reasonable to conclude that inadequate inter-organizational information flows served to lessen interorganizational coordination and effectiveness.

(3) **Planning.** A third general conclusion regarded the lack of prior planning on the part of organizations which retarded interorganizational coordination and organizational effectiveness. The Special Studies Group of the Nuclear Regulatory Commission (no date) noted that confusion existed over the size of the area to evacuate because of a lack of prior plans, that no local plans existed to carry out evacuation, and that the lack of local plans led to a less effective response to the emergency. This same conclusion was reached by the President's Commission on the Accident at Three Mile Island (Dynes et al., 1979: 15) in that a lack of plans that specified specific responsibilities led to a less effective organizational response to the emergency.

(4) **Funding.** The lack of plans was not entirely an oversight. The special Studies Group of the Nuclear Regulatory Commission (no date, p. 1024) sought to explain why there was a lack of plans at the local level. They concluded that the lack of funds was a major constraint to developing the plans.

(5) **Coordination.** The President's Commission on the Accident at Three Mile Island and the Special Studies Group of the Nuclear Regulatory

Commission both concluded that interorganizational coordination was poor in response to the emergency. Furthermore, no mechanism existed to coordinate the response of the various involved federal agencies (Special Studies Group of the Nuclear Regulatory Commission, no date: 1024). The President's Commission observed that interaction between the Nuclear Regulatory Commission, Metropolitan Edison, and state and local emergency organizations was inadequate for the development of emergency preparedness plans prior to the accident. Planning lacked an emphasis on coordination, and response was less than adequately coordinated. The lack of coordination hampered an effective response.

The incident at Three Mile Island, although studied extensively for other reasons, was not well studied from an emergency organizations viewpoint. Nevertheless, several studies provide some evidence to suggest the following set of conclusions about how organizations and their effectiveness can be viewed in such emergencies. First, organizational effectiveness in response to a nuclear plant accident will be reduced if domain consensus exists about which tasks an organization should perform when it is not clearly spelled out in preparedness plans. The lack of domain consensus also constrains effective interorganizational coordination. Second, effective and clear communication and the sharing of information between organizations are essential to response coordination and response effectiveness. Third, preparedness planning, although it is no guarantee, is essential for interorganizational coordination and organizational effectiveness. Fourth, funding for local communities to develop emergency plans will likely increase the odds that they will have such plans. Fifth, interorganizational coordination is essential for an effective response to emergencies caused by a nuclear generating station.

In wake of the TMI accident, a number of researchers have sought to evaluate the plans for nuclear power plant planning including the evacuation planning for TMI (Fisher, 1981); the effectiveness of warning systems at reactor sites (Sorensen, 1984); and the level and quality of interaction between utilities and off-site emergency planning organizations (Sorensen et al., 1984).

4.2.2 Hazardous Materials

4.2.2.1 Behavioral issues

Each year thousands of people evacuate because of spills of hazardous materials. Most spills or leaks occur at fixed plant sites or during transport. Moreover, these accidents are frequently associated with other events such as a collision, derailment, or fire. Combustion, detonation, simple temperature and atmospheric changes, and reactions between or among two or more hazardous material can increase the variable threats to people and property in geometric progression (Cashman, 1983). Often a dangerous chemical is involved, but munitions transport or hazardous waste also pose problems. Despite the large number of evacuations, few have been studied because of the rapidity of onset of the event and the randomness of accident locations.

Three major studies have been published that have used survey data to study evacuation behavior. One is the Mississauga, Canada, incident involving a train derailment which released chlorine gas (Liverman and Wilson, 1981; Burton, 1981). The Burton (1981) report is based on six surveys of the public and businesses. Using semi-structured interviews, the author studied the responses of key actors and members of the public who represented special populations. A second incident with hazardous propane also involved a train derailment near Puget Sound, Washington (Perry and Mushkatel, 1984). The third study investigated a fireworks explosion in Houston, Texas (Killian, 1956). Another type of study (Fowlkes and Miller, 1982) used a small interview sample (63 people) of Love Canal, New York, homeowners to study the behavioral response to toxic waste underground migration that resulted in closure of a residential area and permanent relocation for many homeowners.

At the organizational level, the Disaster Research Center (DRC) has analyzed 20 chemical accidents (Quarantelli, 1981a). This includes detailed case studies of three incidents (Gray, 1981b) and an in-depth study of the Taft, Louisiana, explosion at the Union Carbide Plant (Quarantelli, 1983). The Mississauga incident has also been analyzed from a police organizational perspective (Scanlon, et al., 1980).

4.2.2.2 Risk and risk perception

Other than the Love Canal situation, the studies indicate no major problems with getting people to evacuate. People tend to view the evacuations as inconvenient rather than threatening (Burton, 1981). People are more likely, however, to evacuate when they perceive the situations to be personally threatening (Perry and Mushkatel, 1984). Over time, the ambiguity and lack of clarification of the perceived toxic-chemicals threat caused the Love Canal residents to mistrust officials who were handling the risk situation (Fowlkes and Miller, 1982). When officials do not make decisions in the face of an uncertain accident situation, nongovernment participants (e.g., radio stations) have expanded their role and have taken charge of disseminating evacuation recommendations (Fitzpatrick and Waxman, 1972).

At Mississauga, a number of residents evacuated before official orders were issued (Liverman and Wilson, 1981). The main stimuli for evacuation were media reports and police requests (Liverman and Wilson, 1981). Evacuation occurred outside the official zones (Burton, 1981) but resulted in no negative consequences. Multiple moves were common, with 25% of the evacuees having to evacuate more than once (Liverman and Wilson, 1981). Evacuation decisions were made quickly. Over 50% of the evacuees left within 30 minutes, and 80% were gone before an hour had passed (Burton, 1981). Most residents (97%) did not regret leaving and indicated they would do so again under similar circumstances, even though it was a stressful experience (Liverman and Wilson, 1981). The Scanlon, et al., (1980) report the police did not force residents to evacuate who appeared "mentally competent" and wanted to remain in their homes. However, the evidence suggests that almost all people in the first stage of

the evacuation (about 3500) left when advised to do so by police. As the media picked up the story, many residents left before being warned by police (Scanlon, et al., 1980).

4.2.2.3 Warning experience

In the propane incident, evacuation was determined in part by the belief in the warning issued and the level of perceived risk (Perry and Mushkatel, 1984). Both belief in the warning and the perceived level of risk were influenced by the specificity of the warning received and the credibility of the warning source. Confirmation also played a role in shaping warning belief. Overall, the evacuation process was similar to that found in flood situations.

Love Canal presented an alternative scenario. Because of the ambiguity and uncertainty about the seriousness of the chemical migration, there was general distrust of both officials and experts. Beliefs concerning the magnitude of the chemical migration were highly correlated with age and the presence of dependent children (Fowlkes and Miller, 1982). Social structural factors and the desire for evidence influenced both the access and attentiveness to information and perceptions of the relevance of the information (Fowlkes and Miller, 1982).

4.2.2.4 Evacuation experience

The Disaster Research Center studies provide additional insight into evacuation processes (Quarantelli, 1984; 1982a; 1981a; 1981b). Most evacuations occurring in response to transport accidents are spontaneous with warnings usually spread by word of mouth. Response is quick; most people view the situation as dangerous and react promptly. Response is usually spontaneous and not based on formal evacuation plans. Mass media rarely plays a major role in evacuations. Problems are frequently encountered in these ad-hoc efforts. Warning messages are frequently incomplete and vague (Gray, 1981a). In addition, little guidance on reentry is given evacuees (Quarantelli, 1981a; 1984). Overall, most communities are not well prepared for evacuations following transportation accidents (Quarantelli, 1982a).

4.2.2.5 Planning issues

Both the private and public sectors respond to hazardous material emergencies. Often the specific chemicals involved cannot be immediately identified as was the case in the Mississauga incident. Frequently, special equipment and specialized training are needed for effective response to hazardous material emergencies. Thus, response often involves calling in specialist teams from the manufacturer of the substance or from one of the commercial response teams. Nearly every chemical manufacturing and processing firm has company personnel who are

on call at all times to respond to incidents involving their company's products (Cashman,1983).

Deciding who has command over the evacuation is frequently a problem. Lack of responsible command organizations creates delays in decisions to evacuate and problems in implementing decisions (Quarantelli, 1981b). This often occurs due to poor pre-emergency planning (Gray, 1981a). Small communities that do not have a designated official to handle hazardous material accidents have difficulty in deciding whether to evacuate (Fitzpatrick and Waxman, 1972). Uncertainties regarding jurisdictional authority, lack of outside assistance, poor communication between public agencies and private companies, and inadequate resources also constrain evacuation efforts (Quarantelli, 1984). Differing definitions of risk by local and state officials also lead to problems in evacuation decisions (Albert and Segaloff, 1962).

The cost of such evacuations may be extensive. During the extended evacuation in Mississauga, businesses lost an estimated $50 million. The average cost of evacuation to households was $200 plus $90 in lost wages (Burton, 1981).

Reentry and convergence are frequent problems during evacuations. Perimeter control of evacuated areas was found difficult to maintain, especially when the Mississauga evacuation was extended. Officials at Mississauga assigned special personnel to entry points and made arrangements for animal care workers to feed pets that were left in the evacuated areas (Scanlon et al., 1980). This presented problems later when residents were allowed back into the area only to find that their house keys were not available. An all-clear signal following an evacuation due to a ammonia gas releases led to traffic jams when people, who had evacuated in an orderly fashion, attempted to return to their residences (Albert and Segaloff, 1962).

Planning for permanent relocation of families, following the Love Canal toxic waste migration, had problems due to lack of credibility of authorities and lack of communication during the relocation process. Similar problems in relocation occurred at Times Beach, Missouri, following the discovery of Dioxin contamination.

The case study of the Taft, Louisiana, evacuation highlights several general findings (Quarantelli, 1983). The response to the emergency was governed by the adaptation of plans for other events rather than by pre-established plans. Local officials were not adequately informed which hindered evacuation decisions. Once decisions were made, 17,000 people were evacuated in darkness and rain in a period of two hours. No traffic congestion or accidents were reported.

4.2.3 Nuclear Crisis Situations

4.2.3.1 Behavioral issues

Behavioral studies regarding this category of evacuations are somewhat constrained by the lack of historical incidents. Several studies of conventional wartime evacuations and population movement or resettlements have been conducted (Bernard and Kile, 1952; Zelinsky, 1985). It is unclear, however, whether the differences between those social settings as well as the nature of the threats make generalizing suspect. FEMA and it predecessors have sponsored a variety of research to support evacuations under crisis conditions and has documented attempts to develop plans. This research has included behavioral studies of warning response and evacuation behavior (Perry, 1982; Perry et al., 1980; Rudolph, 1983); and organizational response (Sullivan et. al., 1978; Hoegh, 1977).

In addition, considerable survey research has been conducted in which the public's attitudes and perceptions about nuclear war have been measured (Nehnevajsa, 1979; 1983; Garrett, 1971). These surveys have provided data on public attitudes concerning the efficacy of relocation, desirability of crisis relocation planning (CRP) programs, willingness to relocate, likelihood of evacuation, compliance with others to evacuate, and the survivability of a relocation.

These attitudinal studies provide valuable information on the characteristics of people holding certain beliefs. They suffer, however, from the same problems that limit the utility of behavioral intentions studies for other hazards. The problem is that behaviors in an actual crisis may differ from intentions and may, in fact, conform to the prevailing situational factors that are strong influences on response. These surveys need to be grounded with other types of behavioral research to provide a more firm basis for developing planning assumptions.

A large number of critiques of crisis relocation planning programs have been published. These have ranged from general statements about the feasibility and desirability of this program to detailed reviews of specific aspects of planning. Baffin and Kilpatrick (1982) argue about the necessity of CRP as a strategic defense capability versus the advantages of a sheltering program. Herr (1984) advances a rather shallow argument that the public would not participate in a directed relocation. Hilburn and Parker (1983) suggest that the chief problems of CRP are due to inadequate planning for resources to support evacuees. Katz (1982) suggests that the economic effects of an evacuation as well as the social disruption are unacceptable.

Leaning and Keyes (1984a) have assembled a set of articles challenging the feasibility of CRP based on ethical, emotional, and technical arguments regarding the behavior of individuals and organizations in a crisis situation. Their chief argument is that CRP is unacceptable because it increases the probability of a nuclear war (Leaning and Keyes, 1984b). Unfortunately this argument, which is not substantiated with any careful analysis, detracts from some valid points raised in several of

the essays. This is also true of several other essays which are somewhat tautological, as well as based on rather imprecise logical arguments. For example, Schon (1984) refutes the external validity of three studies as being "articles of faith" being promoted by "survivalists," but he is unable to articulate why the problems "lie beyond analysis." Other essays explore the topics of governance (Lipsky, 1984), sheltering (Susskind, 1984), evacuation time estimates (Brand, 1984), the problems of children (Redlener, 1984) and medical problems (Geiger, 1984). These papers all raise some valid issues regarding problems of implementing a massive relocation, although at times these issues are obscured by rhetorical arguments.

4.2.3.2 Risk and risk perception

While there has been a considerable amount of negative response to crisis evacuation planning in the media, this sentiment is not fully supported by the results of attitudinal surveys of the general public (Garrett, 1971). Since 1963, when the public was first surveyed regarding the desirability of strategic evacuations of cities in a crisis situation, the majority of the population has favored this strategy. Support, however, has decreased from a high of 82% in 1963, to a low of 58% in 1972, but increased to 65% in 1978. Some geographical differences in support are found. Greater support comes from poorer rural areas than from more wealthy urban areas.

Similar levels of support are found for the development of crisis relocation plans (Nehnevajsa, 1983). Support for plans is more universally accepted around the country than the philosophical basis for the strategy. Despite the support on a general level, other forms of protective action are viewed by the public as more efficacious should an attack occur and have also received high levels of public support (Nehnevajsa, 1979). The main factor constraining beliefs that relocation would work is the lack of warning and implementation time (Nehnevajsa, 1983).

Mack and Baker (1961) studied three inadvertent soundings of civil defense air raid alarms to determine if people responded to these warnings of imminent attack. They found that few people interpreted the sirens as signalling an attack and that most did not understand the meaning of the sirens and took any action.

4.2.3.3 Behavioral intents

Considerable data have been collected on intended behavior in a crisis situation. These data suggest that if a crisis situation is perceived by the public as leading to a nuclear exchange, it is likely that a portion of the population would evacuate without an order to do so. This number is largely unknown and will depend on the nature and development of the situation. People who evacuate "spontaneously," however, will not necessarily place themselves at lower risk. A reasonable

estimate of the portion who would leave ranges between 20 and 50% of the population. Evacuation rates would likely be higher from less affluent portions of the country but would not likely be affected by proximity to high-risk locations (Nehnevajsa, 1983).

The number leaving would likely be significantly increased if the President or some other government agency urged or ordered the public to evacuate (Rogers, 1980). The greatest effect would likely come in areas with lower propensities for spontaneous evacuation. While some variations would exist in evacuation rates around the country, they would not likely be great (Nehnevajsa, 1983). The main reasons for not complying with an evacuation recommendation are ideological in nature (Garrett, 1971). Of those who indicate they would comply, about two-thirds said they would follow instructions of officials regarding the logistics of the evacuation (Nehnevajsa, 1983). Those people most likely to follow instructions are from less affluent areas that have a stable population.

4.2.3.4 Planning issues

Several studies have sought to apply findings derived from studies of natural disasters to war-related evacuation planning (Ickle and Kincaid, 1956, Perry et al., 1980; Perry, 1982). According to Perry (1982), crisis relation planning can be interpreted within the context of emergent norm theory of collective behavior. The objective of CRP is to move citizens out of an area before an attack begins. Thus, warning response behavior in the event of nuclear attack situations does not differ from that behavior elicited in natural disasters. Perry argues that every disaster agent has some unique characteristics with nuclear events having as much within category variation as between category variation. Thus, the focus should be on developing generic means of coping with hazards. There are four essential conditions that ensure a decision to relocate: (1) the individual must have an adaptive plan, (2) the individual must perceive that personal risk involved in not relocating is high, (3) the threat must be perceived as real, and (4) the individual must have either the family (household) assembled to evacuate or have all members accounted for and not in danger. Emergency managers must address two activities:

1. identifying appropriate adaptive behaviors and strategies for implementing protective action, and

2. educating the relevant population with regard to the particular plan. Incentives recommended include information on safe destinations and plausible safety routes given in advance or as part of warning message, development of warning-confirmation centers based on telephone contacts, establishment of family message centers, and development of some form of security measures for areas evacuated.

4.3 MULTI HAZARD EVACUATION RESEARCH

Several multiple-hazards studies have focused on the social characteristics of response to warnings as they relate to other human behavior. Aquirre (1983) analyzed the relationship of human evacuation to migration, suggesting that evacuation can be viewed in the broader context of geographical mobility. Focusing on the variables of distance, permanence, and voluntarism used to distinguish evacuation from migration, he finds the clear-cut distinctions unwarranted. Arguing that future work should ascertain how findings regarding migration contribute to understanding specific propositions of evacuations and vice versa, Aquirre notes it is possible to study evacuation and migration in three models: (1) as residential displacement, (2) in the context of subjective decision-making processes triggered by stresses, and (3) from the collective behavior standpoint. As mass movements, evacuations often represent a collective behavior response wherein the evacuee is forced "to synthesize the elements of an emergent and collective situation to give consistency, orientation, and meaning to his act" (Aquirre, 1983; p. 425). Thus evacuation shares with migration conceptual and substantive elements which are interdependent under of the overall umbrella of geographical mobility.

Fritz (1957), in comparing disasters in six American communities, found that individuals interpret disaster events differently, depending on the immediate spatial cues but within a normal frame of reference. Initial behavior in disasters is not necessarily maladaptive or irrational but uncoordinated. To coordinate behavior, Fritz suggests substituting a collective or common definition through communication channels to aid coordination of behavior. Fritz found "scapegoating" and resentment by victims unusual unless rehabilitation efforts were perceived as discriminating among victims. Persons with the most extreme losses often exhibit no resentment or aggression. Fritz notes that maximum social and psychological disruption occurs when families or primary groups are separated. Fritz also found that emergent leaders in a disaster are often those with previous similar experience (i.e., firemen, priests, utility personnel) or those persons with no ego involvement in the situation.

In the NORC Studies (Fritz and Mark, 1954), data from 70 major and minor disasters revealed that, although reactions varied considerably both individually as well as with event type, general "modes" of reaction could be distinguished according to activity level varying from agitated to depressive. Panic flight appeared to occur under restricted conditions and for only some people. Panic flight may occur when the individual believes the situation is personally threatening or when escape is possible at the moment but may become impossible in the immediate future. Fritz and Mark (1954) suggest that such behavior is not caused by the irrational or uncontrolled nature of individuals but by a lack of coordination among large numbers of persons who have very different personal conceptions of the situation. They found evidence that inadequate forewarning may actually cause losses that would not have occurred if there had been no warning at all. In addition, they

found evidence that emotional reactions appeared aggravated by experiences such as being separated from family members and having intimate contact with the dead or injured.

In another study concerning humans in disasters, Fritz and Williams (1957) analyzed 40 disaster studies and found that disaster warnings need to be clear and specific and transmitted through channels to the entire public. Lack of prior experience with the disaster agent and the delusion of personal invulnerability interfere with the individual's ability to adopt a new frame of reference, especially if no prior warnings are given. Besides noting the lack of panic in disaster situations, they found that controlling the convergence behavior of outsiders not of the victims themselves was the problem. Fritz and Williams also found increased social stability during an emergency which influenced both personal and social recuperation. Hostility and blame were not common to victims who essentially were "future-oriented"--searching for amelioration of future threat. They suggest that "issue-makers" may use mass media to foster "scapegoats" for their own purposes. In managing disasters, a lack of "fit" between perceptions of the needs of victims and organized relief operations was apparent.

Perry (1979a; 1979b) reviewed and summarized empirical studies of warning responses, focusing on voluntary pre-impact evacuation behavior. He notes that earlier studies lacked analytic models to identify variables and specify patterns. The later system's models had to be supplemented by some form of social psychological model to enhance the framework and to allow concurrent analysis of the individual and community levels. A model adapting the integrated systems approach with the emergent norm perspective permitted the "temporal ordering of factors" in personal reactions to warnings. Perry hypothesizes eight causal factors that contribute to the individual's decision to evacuate. As presented by Perry (1979a) the factors that can (a) increase the possibility of evacuation are

(1) a more precise the individual adaptive plan,

(2) a better individual perception of the real threat (warning belief),

(3) a higher level of perceived risk,

(4) the fact that family (household) members are together or accounted for,

(5) a closer relationship to extended kin,

(6) a greater participation in the community,

and factors that can (b) lessen the possibility of evacuation are

(1) families headed by aged persons, or extended-family households containing aged, and

(2) cultural factors such as race/ethnicity.

In another article, Perry (1979b) formulates a number of recommendations for building "incentives to evacuate" into warning systems, using normal behavioral tendencies observed in past warning responses. In yet another study, Perry, Greene, and Lindell (1980) provide a further articulation of these incentives. They argue that warnings are relatively useless without a community evacuation plan. They also contend that warning messages should be as specific as possible regarding the type of threat, the probable time of impact, and suggestions for appropriate actions. They found from a study of four flood-stricken communities that evacuees did not necessarily hear about the availability of shelter from the warning message. Although evacuees clearly prefer homes of relatives or friends as refuge, use of public shelters increases when community preparation is high, when entire communities are evacuated, or when a long duration of evacuation is anticipated. When flooding is a recurrent pattern and a disaster subculture exists, the use of public shelters tends to be low. The authors note that as forewarning time shortens and community preparation is low, people will first seek known protection which may not always be in their best interests. Programs are advocated for educating the public about emergency plans. The data also indicate that families tend to evacuate as units, and this concept of "symbolic security" regarding security measures is supported by the research. Furthermore, the data suggest that the public is receptive to the idea of officially provided transportation for evacuation as well as the concept of "family message centers," both of which could be used in planning to enhance evacuation response.

Panic, as a behavioral response, has been researched extensively. Quarantelli determined from data gathered by the Disaster Team of the National Opinion Research Center and other documented sources that the frequency of panic behavior had been overstated in the disaster literature (Quarantelli, 1954; 1957). He found that panic behavior occurred under specific conditions in which the participant engaged not in antisocial behavior but rather in a type of non-social action. "Such behavior arises upon a definition of entrapment, a perception of collective powerlessness, and a feeling of individual isolation in a crisis" (Quarantelli, 1954). He also notes "the most important condition for the occurrence and continuance of panic is the feeling on the part of the participant that he may be unable to escape from an impending event." The non-social behavior is short-lived but is a distinguishing feature from that of controlled withdrawal. In addition, Quarantelli noted that contributory panic conditions may include the preexistence of a group's definition of a crisis situation or sensitization of the individual who has experienced a prior crisis event.

Quarantelli (1960), in a theoretical synthesis of studies through 1960, noted that basic misconceptions of evacuation in disasters and mass emergencies existed. These myths included the notion that disaster-victims almost never panic; instead flight behavior is prudent and controlled, and the notion that passive-victims are rarely inactive; victims instead actively participate in extensive patterns of informal aid and self help. In addition, the total organizational breakdown of control over withdrawal behavior is seen both as impossible as well as dysfunctional (cited in Quarantelli, 1980).

The topic of convergence behavior in disasters has been discussed by Fritz and Mathewson (1957). They define three types of convergence: personal, informational, and material. A typology of convergence is developed by distinguishing five different groups according to motivations for converging: returnees, anxious, helpers, curious, and exploiters. Often convergers, including friends and relatives of victims sent to recover possessions, are mistaken for looters. Fritz and Mathewson's work indicates that convergers hinder official organizational efforts to evacuate during rescue and to conduct relief operations. This problem particularly hindered the evacuation of people after a tornado (Taylor et al., 1970; Wallace; 1956).

Strope, Devaney, and Nehnevajsa (1977) analyzed results from data related to existing emergency plans and pre-disaster public information activities that may have included prior tests and/or exercises involving either or both disaster organizations or the public. Data from 57 evacuations suggest that drills and tests differ substantially from real events; therefore, such exercises are neither economic nor representative of the population's ability to cope in an emergency. Although records of disasters are incomplete, some evidence exists that public drills may be counterproductive. Commonly, post-disaster audits made recommendations for improved plans, equipment procurements, and infrastructure changes, but they did not find support for conducting any more public drills or exercises. They also found that inducing public participation in drills is difficult and may even introduce misinformation and ambiguity when a subsequent emergency arises, limit response flexibility, and degrade information-source credibility. They further found that information efforts to educate the public prior to an event had a limited effect.

At the organizational level, Strope, Devaney, and Nehnevajsa (1977) found that evacuations have routinely been successful even when no specific plans were made in advance. When plans were utilized in an event, familiarity of officials with those plans appeared the most important factor. They suggest that efforts be made to enhance organizational infrastructure and effectiveness, including the advance preparation of warning messages and their means of dissemination. Public pre-disaster information should be limited to enhancing credibility of authority sources used during an emergency.

Researchers have also looked at the problem of role conflict, strain, or abandonment by emergency workers in times of emergencies. The notion is that emergency workers have two competing roles in an emergency: to perform their emergency duties and to attend to family or intimates who are at risk from the emergency. It follows from this concept that during an evacuation workers might decide to abandon their emergency roles and fail to carry out their duties. Mileti (1985) has recently examined the concept as first conceptualized by Killian (1952) and later discussed by Moore (1958), Fritz (1961), Bates et al. (1963), Dynes (1970), Barton (1969), and Quarantelli (no date). The prevailing line of thought on role conflict is that, while people likely will experience conflict between family and organizational responsibilities, roles are rarely abandoned, and performing multiple roles does not jeopardize emergency duties.

Mileti (1985) concludes that when emergency work roles are "certain"--perhaps through training or planning--emergency workers do not abandon work roles to attend to roles involving intimate relationships. When emergency work roles are not "certain," than role conflict can occur, and would-be workers could attend to personal or family duties before attending to emergency duties. Mileti concludes that role conflict can elicit psychological stress or at least concern about safety of intimates. However, if the worker has a clear image of the emergency work role (which can be achieved through planning or training) then in an emergency he/she can resolve role conflict and fulfill the emergency work role while improvising ways to check on the safety of intimates.

4.4 MODELS OF EVACUATION BEHAVIOR

Behavioral scientists have formulated two classes of models associated with evacuation behavior. The first type of model is descriptive or process-oriented. These models attempt to describe the process or steps that people go through in arriving at a decision to evacuate or to do something else. The models are based on a time sequence of events, questions, information flows, and decisions.

The second type of model seeks to explain why people evacuate. These models generally attempt to identify the multivariate "causes" or factors that explain why some people evacuate and why others do not. They are concerned with a broad set of factors including social context, attitudes, perception, constraints, and other social and psychological constructs.

4.4.1 Evacuation Decision Processes

Models have been developed to describe the individual or family decision process and the organizational decision process, including the linkages between the two. Often models have been couched in a broader decision context of alternative protective actions where evacuation is only one possible behavior. These models have emerged over a period of

time in which various iterations of a model were designed, field-tested and subsequently revised. Flow diagrams have been developed to help visualize the process described by the models. Four of these models, representing current thinking about decision processes, are reviewed here.

4.4.1.1 Emergency decision model

Perry and Mushkatel (1984) as well as other of Perry's publications describe an emergency decision-making model for natural disasters. The model is shown in Fig. 4-1. The evacuation process is initiated upon receiving a message regarding an environmental threat. A series of questions then follows. A negative response at any stage leads to inaction. At the next stage a person asks if the threat really exists. Influencing the internal answer to this question are the presence of environmental cues, confirmation, and perception of credibility of the warning source. If a threat does exist, the person then must assess whether or not the risk is personal. This assessment is influenced by the content of the message received and the person's previous experience. If the threat is real and personal, the person then asks if protection is possible. This is influenced by past experience and knowledge about the threat. The evaluation of protective action is followed by asking if the person can take that action. This is shaped by timing, family context, and having a plan of action. The next question is whether action will significantly reduce the threat or consequences. The evaluation of effectiveness is thought to be influenced by past experience and sociocultural beliefs.

Finally, the person evaluates a recommended action. If this action is in agreement with his or her own assessment of the situation, he/she will likely follow the recommendation. If not, other choices are reviewed while taking into account what friends, kin, and neighbors are doing and their own conventional wisdom. Persons-at-risk then proceed to take the action perceived to minimize the negative consequences.

4.4.1.2 Model of warning response

A slightly different model of warning response has been advanced by Mileti and Sorensen (in press). The model also suggests a staged set of processes over time but is less rigid in its structure (Fig. 4-2). The evacuation (or other protective action) process is initiated when the warning is heard. Hearing a warning is insufficient by itself, in many cases, for people to evacuate. The next stage is understanding the warning. Understanding involves the formation of mental images of the message content consistent with the threat situation. After understanding, people must come to believe that the warning is true and accurate. Next, people must interpret the message as being relevant to themselves--personalizing. Finally, they must decide to take action and overcome constraints to taking that course of action. Throughout the process a variety of factors influence hearing,

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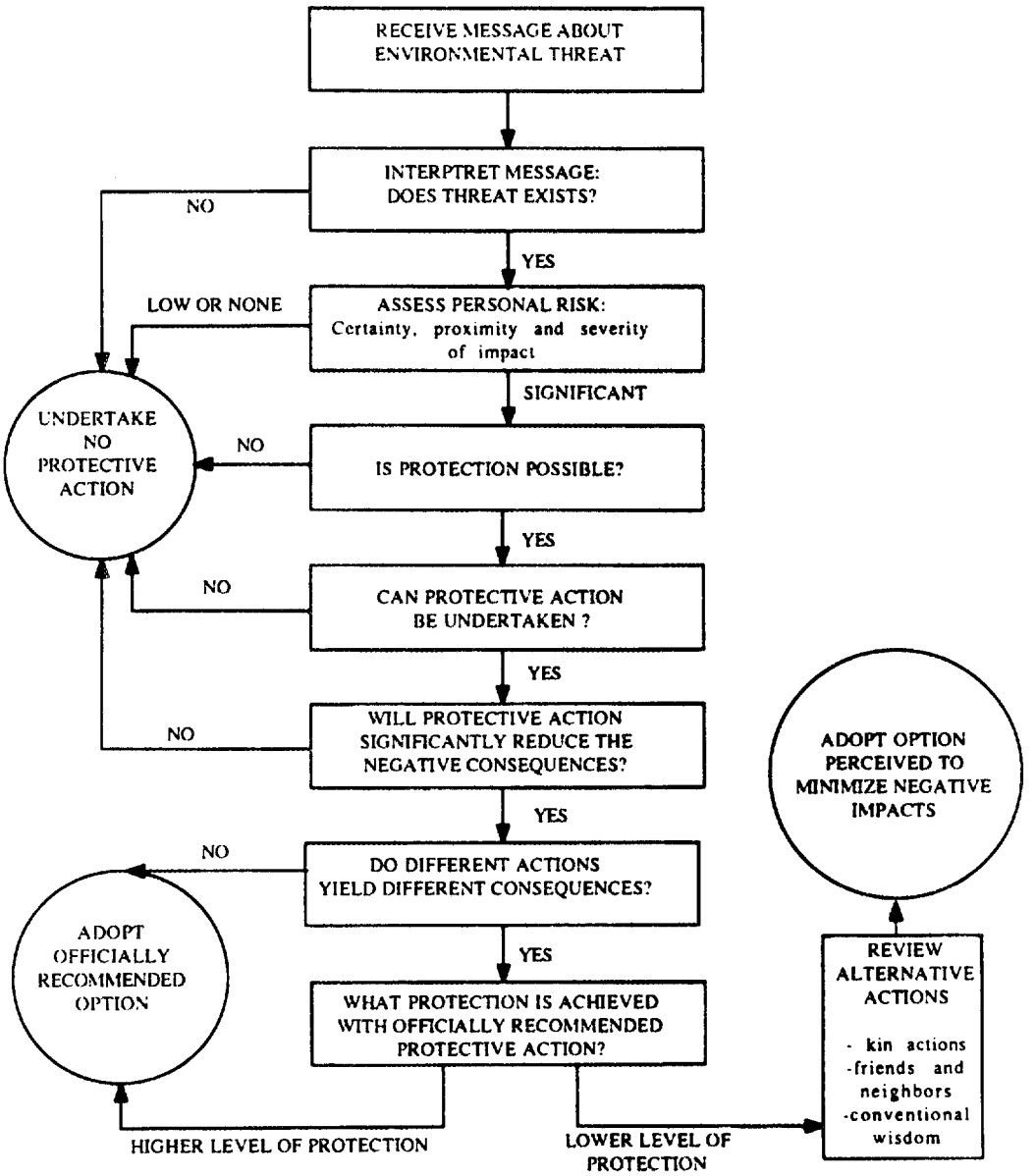

Fig. 4-1. Emergency decision-making model.
Source: Perry and Mushkatel, 1984

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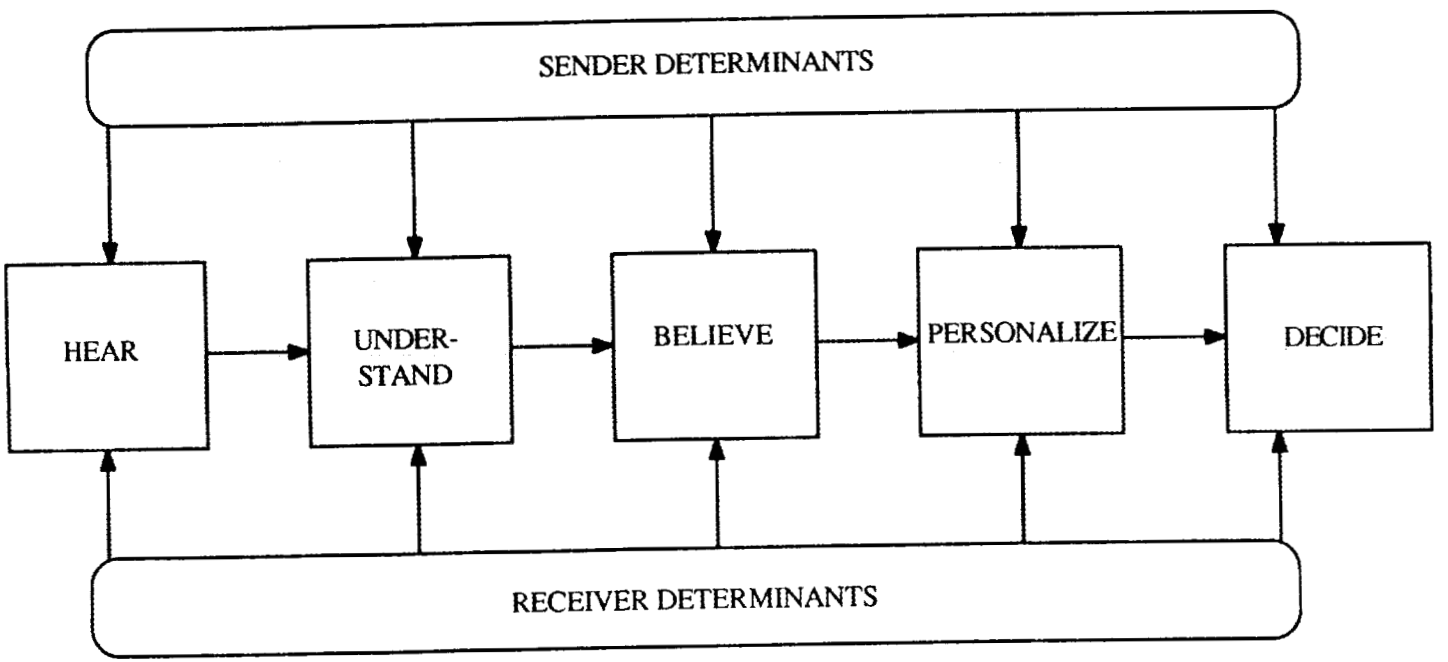

Fig. 4-2. Model of warning response. Source: Mileti and Sorensen (in press)

understanding, believing, personalizing, deciding, and behaving. These relate to the nature of the warning effort, the characteristics of the receiver, and the process of confirming the warning information.

4.4.1.3 Conflict theory of emergency decisions

Janis and Mann (1977) present a theoretical model of emergency warning response. They introduce the concept of adaptive behavior which is defined as making effective protective decisions under a vigilant coping pattern. Four conditions characterize effective coping. First, an awareness of serious risk if protective action is not taken. Second, an awareness of serious risk if any of the immediately perceived protective actions are taken. Third, the hope that a search for more information will lead to a better solution. Fourth, the belief that there is time to search and make a better decision.

The model results in five patterns of behavior. Not perceiving a threat leads to "unconflicted inertia" or the continuation of normal activities. Satisfaction that an intended behavior will reduce the risk is labeled "unconflicted change." The absence of hope to find a better means of coping leads to a condition they call "defense avoidance" where people become inattentive, assign blame to others, or ignore the situation. Perceiving that there is not time to find a solution leads to "hypervigilance" where people may imitate the behavior of others or, at the extreme, panic. Meeting all four conditions is called "vigilance" and leads to a new course of protective response.

4.4.1.4 Model of an evacuation decision system

A model of organizational decision processes in evacuation has been developed by Sorensen and Mileti (in press; Mileti et al., 1985). This model defines the general component, common decision points, and linkages that are somewhat characteristic of all evacuation decisions. The key decision points and communication linkages which define the process are illustrated in Fig. 4-3. The model has three basic components: a detection subsystem, an emergency management subsystem, and a public response subsystem. The initial stage in the decision-making process is the detection of hazard or the recognition that the environment poses a hazard. Once the hazard is detected, the second key decision is whether or not the hazard poses a threat. Once the threat is judged to be significant, the detector/assessor must decide whether or not to alert the public or officials of the risk and potential damages and then, who should be notified of the threat. A notification of a public official typically results in the activation of an emergency response structure. The organization initially notified must decide who else to involve in a decision to evacuate. Once mobilized, a decision must be made by emergency managers as to whether the risks warrant warning or protective action. Finally, a decision is made as to what type of protective action is needed and whether or how to warn the public.

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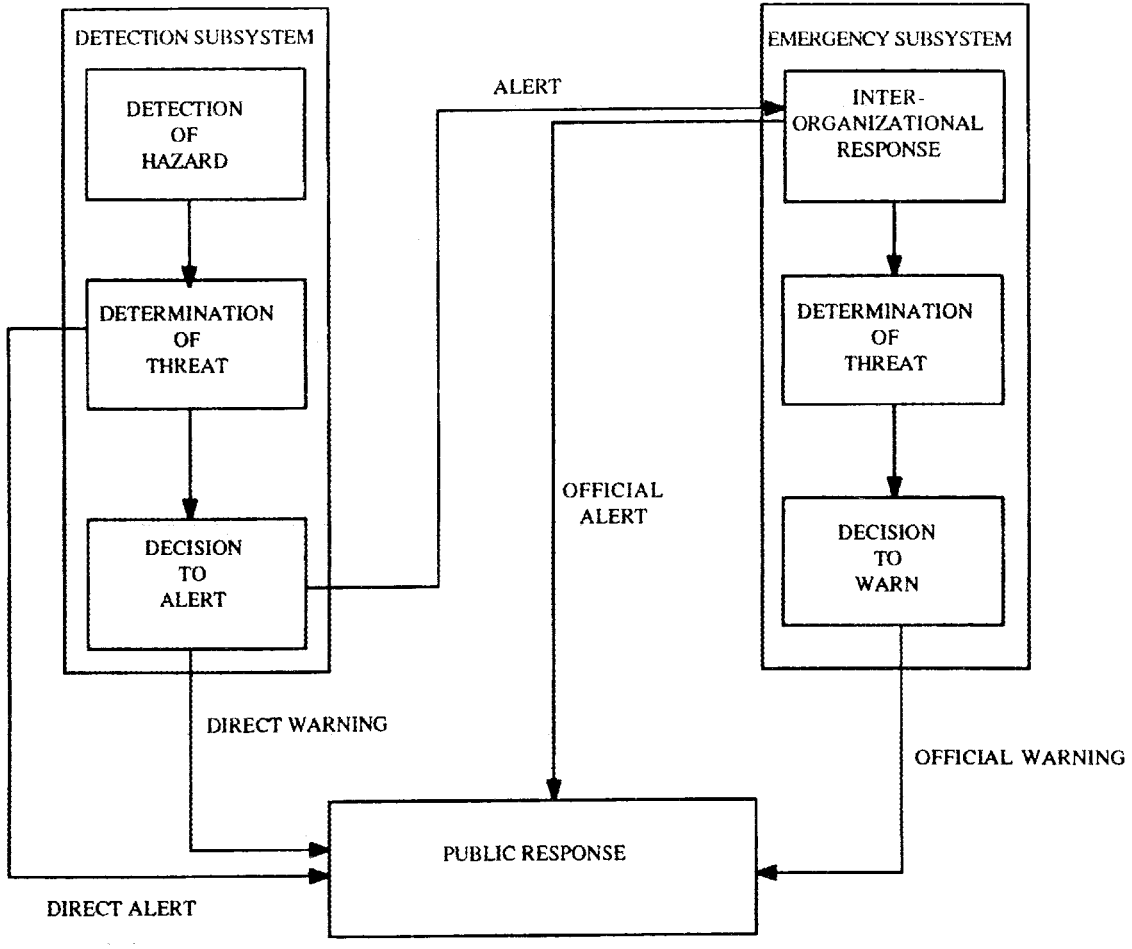

Fig. 4-3. Model of an evacuation decision system. Source: Sorensen and Mileti (in press)

This model illustrates that the organizational component of an evacuation can range from a simple situation involving a citizen-generated detection and alert mechanism to a complex situation involving a large scientific monitoring program accompanied by a bureaucratic government decision structure. The process is often interactive with numerous dynamic communication flows regardless of the scale and complexity.

4.4.2 Explanatory Models

Several conceptual models of warnings response have been developed to explain variations in the outcome of the emergency decision process at the individual level. Model development has involved theory building by empirically testing hypotheses using multivariate analyses of behavioral surveys. These models have evolved over time through replication and revision of a series of hypotheses or through application of more general behavioral theories derived from the study of other phenomena.

No attempt has been made to develop such a model at the organizational level because of the lack of comparable data from a sufficiently large number of emergencies and because of difficulties in specifying the appropriate variables to analyze (Sorensen et al., 1985). The basis for understanding why some organizations implement an effective evacuation decision process versus a poor one is not well understood.

4.4.2.1 Protective action decision model

Houts et al. (1984) develop a model of evacuation primarily based on the health belief model. This latter model is derived from the study of why people protect themselves against a wide range of health hazards. This model suggests that individuals assess the hazard based on the two characteristics of perceived severity and perceived susceptibility. A person also assesses possible responses in terms of perceived efficacy and the barriers and costs associated with recommended actions. Accordingly, evacuation occurs due to a perception of high severity of the threat accompanied by a perception of high self-vulnerability. Evacuation occurs under these conditions unless barriers prevent it from occurring.

4.4.2.2 Causal model of evacuation decisions

The factors that Perry and Mushkatel (1984) postulate to be important in evacuation decisions and the configuration of those variables are depicted in Fig. 4-4. Four factors are postulated to directly explain the decision to evacuate. These include having a precise adaptive plan, having a high level of perceived personal risk, having a high level of belief in the warning, and having the family together or accounted for when the decision is made. A number of antecedent factors influence variability in these four factors. Having an adaptive

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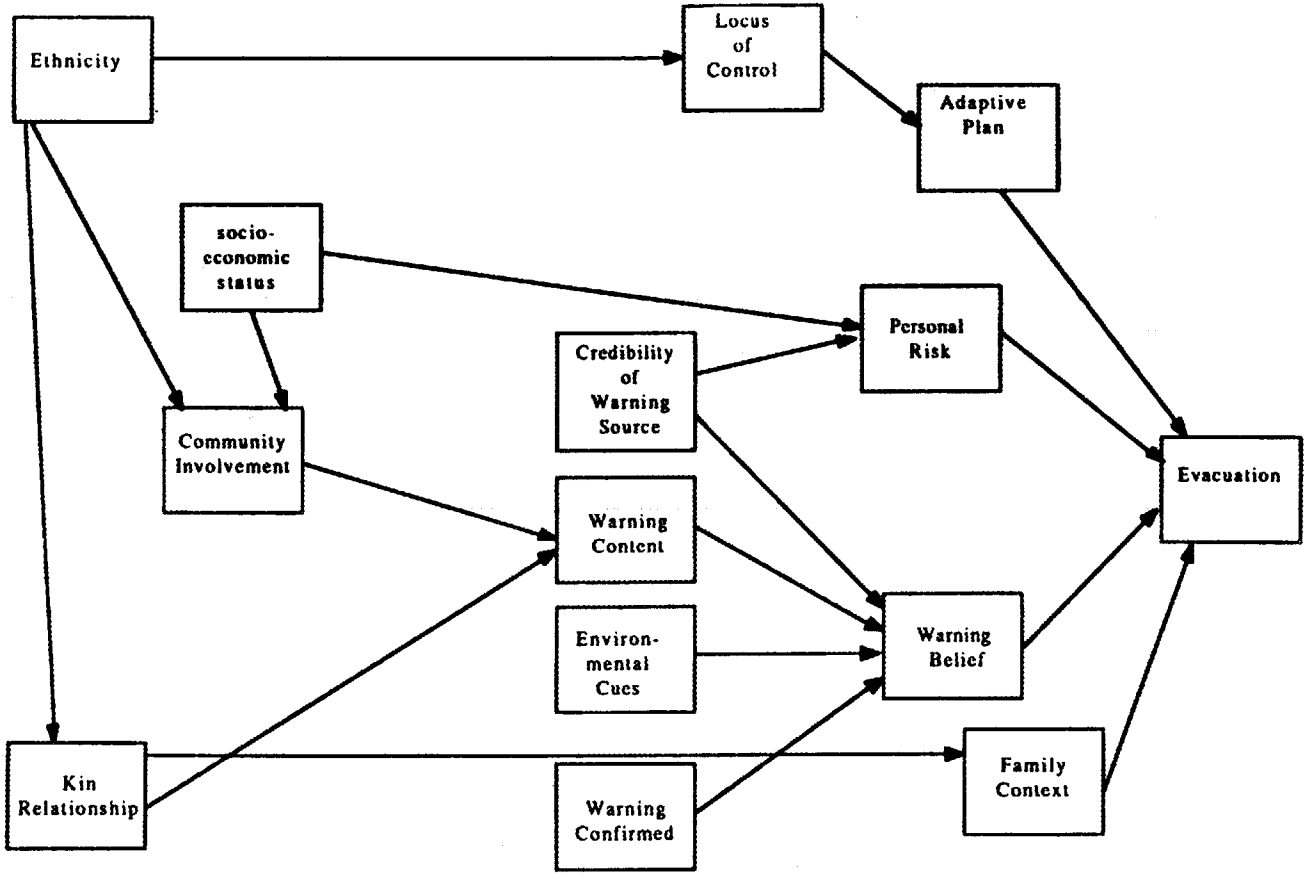

Fig. 4-4. Causal model of evacuation decisions. Source: Perry and Mushkatel, 1984

plan is more likely with an internal locus of control which in turn is influenced by ethnicity. Level of perceived risk is shaped by ethnicity, socioeconomic status, credibility of warning source, and warning content. Warning belief is influenced by warning content credibility and confirmation as well as by environmental cues. Family context is influenced by pre-emergency patterns of kin relations.

Perry and Mushkatel (1984) empirically tested this model for evacuations due to a flood and a hazardous material accident in a rail yard. The results substantiate the model structure for both incidents. A similar model has been used to explain evacuation behavior at Mount St. Helens (Perry and Greene, 1983) and in four flash floods (Perry et al., 1981).

4.4.2.3 General model of evacuation behavior

A general model of evacuation behavior has been developed by Sorensen and Richardson (1984) to attempt to explain evacuation behavior at TMI in light of evacuation processes observed for natural disasters. This model is presented in Fig. 4-5. The model, as others, suggests that perceived threat at the time of the emergency is a major cause of evacuation. Perceived threat and behavior are shaped by information about the emergency coming from the emergency warning system and other sources such as friends or relatives. This basic process of risk perception formation is thought to be influenced by two sets of antecedent factors. As the emergency unfolds, a person's concern with other worries and threats, their perceived ability and resources to cope with the emergency, and their trust in the ability of risk managers are thought to influence how warnings are interpreted, perception of threat, and subsequent behavior. At a more basic level, three pre-emergency factors defined as demographic characteristics (e.g., age, socioeconomic status, family life stage), social ties, and sensitivity to the category or type of threat are important in shaping the emergency response. This process is mediated by hazard-specific, situational factors as well as by situational constraints.

4.4.3 Future Directions

As the empirical base of data on evacuation behavior improves, it is likely that our understanding of why people evacuate will be refined. It is difficult to imagine that existing models of behavior will change dramatically fashion as new evidence is accumulated. Existing models have explained roughly 25 to 50% of the variance in response in any given evacuation. Improvements will likely be made through further refinements of existing model constructs and, more importantly, with better measurement.

Variations in evacuation behavior between different events and between events involving different hazards is much less well understood. The general constructs that explain variation within a single event are, based on limited observation, more likely to be similar

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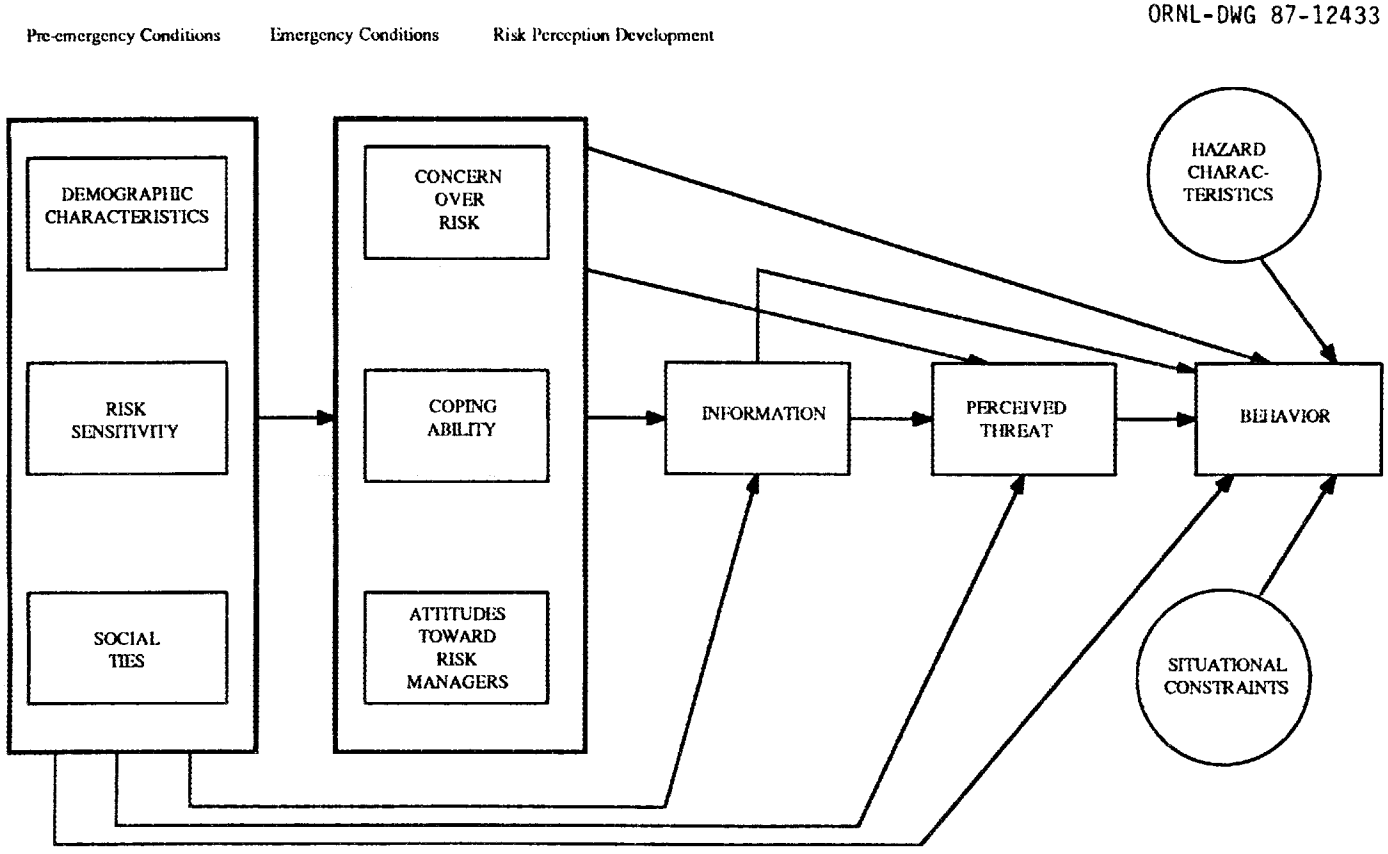

Fig. 4-5. A general model of evacuation behavior.

across events, than radically different. Thus the model that explains flood evacuation decisions will likely also explain hazardous materials or nuclear power plant accident evacuations. Still lacking is a precise explanation of how hazard characteristics and variation in the warning and response experience relates to different evacuation profiles defined by macro variables such as the level and timing of response.

4.5 SUMMARY OF EVACUATION BEHAVIOR IN DISASTER

To conclude this chapter, we have attempted to aggregate data derived from various behavioral studies of evacuation so that we may address four questions frequently raised by emergency managers. First, what types of warning are needed for people to evacuate? Second, how many people evacuate in an emergency? Third, when do people evacuate? Fourth, do people evacuate unnecessarily?

Answers to these questions are based on the aggregation of data from the studies discussed in this chapter. We should caution that the patterns are somewhat tentative because data for the various studies have been collected in different ways, for different purposes, and with different sampling frames and levels of reliability. In addition, the events are very different. Nevertheless, some interesting patterns emerge when available worthwhile data are aggregated. The aggregated data to support these conclusions are summarized in Appendix C.

4.5.1 Evacuation and Warning

Formal warnings greatly facilitate evacuations but are not an absolute prerequisite for evacuations to occur. In the series of events examined in this chapter, the percent of the population warned ranged from 30% to nearly 100% of the population defined by the researcher to be at risk and included in the sample. The poorest warning effort documented by a behavioral study was at the Big Thompson, Colorado, flood, where an estimated 30% received a warning before the waters hit. It is possible that in other disasters, where behavioral surveys have not been done, lower warning rates would be found. In most events, particularly with a lead time of 3 to 4 hours, at least 90 to 100% of the population can be warned without the use of a highly specialized warning system.

People were warned in most events by a mix of three message sources: emergency officials, such as police officers or emergency workers; informal sources, such as friends, neighbors, or relatives; and the mass electronic media, such as radio or television. The mix varies among events, although the reasons for variations in the mix are not well understood.

4.5.2 Evacuation Rates

Evacuation rates are determined by the percentage of the sample-at-risk that evacuated. These rates may be misleading, depending on assumptions about how the sample was defined and whether or not it was representative of the true population at risk. Insufficient information exists to make judgments about such problems. Taking the researchers data at face value, we find evacuation rates ranged from 0 to 98% of the populations at risk. This suggests that the statistic of evacuation rate is relatively meaningless in many evacuation settings. Obviously, this rate is not a good measure of evacuation success. A better measure may well be the injury and fatality rates among the non-evacuees.

In comparing warning rates with evacuation rates, an interesting pattern emerges. In only one of the cases observed, a greater percentage of people evacuate than were warned. In the remaining cases, more were warned than left. This suggests that, in order to achieve a high rate of evacuation when it is prudent due to the risks involved, a high level of warning is needed. This underscores the importance of warning systems to support evacuation planning.

4.5.3 Evacuation Timing

Available data show that evacuation mobilization times or departure times follow a logistic distribution. The shape of the curve and its steepness seem to depend on the urgency of the situation and the time available to leave before the threat is present. In situations like Mississauga, close to 90% of the first group of evacuees left within 60 minutes with nearly 60% departing in 10 minutes or less. In more protracted situations, the same s-curve pattern occurs but is spread out over a longer time frame. People appear to adjust the rapidity of their evacuation behavior in accordance with the severity and timing of the impending threat.

4.5.4 Evacuation and Risk

Fairly limited data suggest that indeed not all people who are defined to be at risk need to evacuate to prevent personal harm. Evacuation rates decrease as level of risk decreases, although not always in a direct linear fashion. In high risk areas, warning systems can achieve a high rate of evacuation. In low risk areas, evacuation rates are significantly lower. Often this is because people at lower risk take some other form of protective action such as sheltering, even though an evacuation is ordered. This suggests that the public may be fairly good appraisers of the microconditions of risk in their environments, but, unfortunately, they are not always correct. Until planning for evacuations can consider risk information at a much more detailed level, this process of citizen risk estimation will likely continue.

5. RESEARCH TO SUPPORT EVACUATION PLANNING

5.1 INTRODUCTION

In this chapter research directly oriented towards evacuation plan development and research findings with direct applicability towards evacuation planning are reviewed and summarized. Work in this area, in general, falls into two broad categories. The first concerns hazard-specific planning studies which can address multiple or a single functional response area. For example, a report may present information and results on an investigation of a traffic time estimate model for nuclear power plants. Another may concern general planning issues for hurricanes. Still another may address issues of traffic control in the face of a crisis evacuation. The second broad category includes studies which investigate a single functional planning topic that cuts across hazards, although may focus on a single or a few specific hazards. For example, a study might focus on warning systems for all climatological events or sheltering issues for all relevant hazards.

Some of the research and to a larger degree practical planning experiences has been summarized into a number of evacuation planning guides. Some of these have been issued by FEMA; others have been developed by states or regions. In many instances, evacuation is addressed as a topic under a broader umbrella of emergency planning activities.

In this section, we have segmented evacuation planning into a number of functional task areas, some are overlapping and some are applicable to broader emergency planning issues. These functional areas are

1. command/control,
2. traffic control,
3. warnings to support evacuation,
4. evacuation strategy,
5. evacuation modeling,
6. special populations,
7. sheltering to support evacuation,
8. evacuation cost, and
9. relocations as evacuations.

5.2 COMMAND/CONTROL

Command/control refers to the management structure used to make evacuation decisions and to control or implement those decisions from an administrative perspective. It also includes planning to manage an evacuation when one occurs.

5.2.1 Management Structure

Management of evacuations and the processes involved in implementing evacuations have been extensively documented. Accounts exist for flood or dam-failure evacuations (Anderson, 1964; Clifford, 1956; Erickson, 1976; Graham and Brown, 1983; Worth and McLuckie, 1977), hurricanes (Chiu et al., 1983; Committee on Science and Technology, 1984; Forrest, 1979; Moore et al., 1963; Savage et al., 1984); tsunami (Anderson, 1970; 1966; 1965; Yutzy, 1964), volcano (Hodge et al., 1979; Sorensen, 1981; Sorensen and Gersmehl, 1980), hazardous materials accidents (Burton, 1981; Gray, 1981a; 1981b; Quarantelli, 1983, 1981b), and nuclear power plant accidents (Chenault et al., 1979; Dynes et al., 1979; Fisher, 1981). Many findings from these studies were reviewed in the previous chapter under the context of organizational behavior in evacuations.

The lack of a centralized command structure may create confusion and delay the issuance of an evacuation notification (Quarantelli, 1986). In addition, a clear hierarchy of authority generally enhances evacuation management. The lack of a management structure may lead to competition for power and authority and, hence, management problems (Sorensen, 1981). In other situations, the lack of a management structure leads to a management void in which no one is willing to assume authority and responsibility (Quarantelli, 1986).

The Emergency Operations Center (EOC) concept is used in most evacuation planning to provide a physical as well as a command structure for evacuation management. The lack of a centralized EOC has been a constraint to effective emergency management in previous events (Saarinen et al., 1984). In the 1986 Cheyenne flood, the loss of the EOC during the emergency led to a breakdown in management when officials turned their efforts to restoring the EOC and neglected the emergency (Sorensen, 1986a). The size of the EOC and equipment in an EOC often influences the effectiveness of the emergency management effort (Dynes et al., 1979). Lack of resources at an EOC (e.g., food and water) can cause problems in maintaining operations (Pinellas County, 1986).

There appears to be a fine line between involving all possible parties and limiting access to the command structure in an EOC. The Pinellas County (1986) evaluation following Hurricane Elena noted that a large number of people in the EOC hampered notification and decision making. On the other hand, not having the key personnel from important agencies led to problems in managing shelter operations. An off-limits or restricted access EOC has been identified as one means of reducing confusion and conflict among managers (Sorensen and Gersmehl, 1980). When a large number of people with minor levels of authority gather in an EOC, those in charge may use information dissemination to maintain control (Sorensen, 1981).

The role of planning to support an effective management structure is not subject to wide debate. The lack of planning, in general, has been cited as a cause of poor evacuation management in many events (Quarantelli, 1980; Brinson, 1980; Chiu et al., 1983; Gray, 1981b;

Scanlon et al., 1980). Stated as a positive relationship, planning enhances management. In a comparative study of two communities, Anderson (1970) found that prior planning led to better command and control of a tsunami-induced evacuation. Others have noted that the lack of specific elements of evacuation planning have led to management problems. For example the lack of specific and predetermined evacuation routes has led to poor evacuation management (Brinson, 1980; Chiu et al., 1983). Others argue that such a detailed level of planning to support management is only needed for complex evacuations (Chenault et al., 1979) and for concurrent hazards (Moore et al., 1964; Sorensen, 1986a).

The media is often a major constraint to effective command and control. Media attempts to gain information frequently interfere with management functions because they divert officials from their official duties (Wenger, 1985a; 1986). Press conferences are planned to control interference from media in managing an evacuation, but this strategy frequently fails. Inaccurate or premature media reports often create problems and extra work for officials and can undermine the management efforts when faulty or inaccurate information is disseminated (Pinellas County, 1986).

Evacuation management structures that serve well in the short-term situations may break down over time periods. The shift of personnel in management from the initial group in charge to the relief group can be problematic (Quarantelli, 1986). Evacuations that must be sustained over a long time frame can lead to the breakdown of command. People begin to question management practices, particularly under ambiguous threat situations (Hodge et al., 1979). Attempts are made to circumvent authority (Sorensen, 1981) or reenter evacuated areas against official orders (Burton,1981). From a similar viewpoint, the management of reentry often gets neglected or overlooked in evacuation planning (Moore et al., 1964).

Management structure has also been researched from a normative viewpoint for both evacuation planning and for emergency management in general. It appears that greatest attention has been given to hazards that are rare or have not been experienced. For example, considerable attention has been given to management structures to support crisis relocation planning. Two lines of thinking have emerged from this research. The first concerns the concept of "organizational relocation" (Chenault and Davis, 1978; Chenault and Gay, 1974; Butler and Rose, 1982; Miller et al., 1980). The purpose of this concept is to prevent the disaggregation of management structure of organizations during an evacuation to preserve authority and coordination. This is done by moving entire management systems into host areas to help govern the evacuees. The idea is based on well-established principles of organizational behavior. The research on the concept has logically developed from concept and rationale to guides and tests of implementability.

The second concerns the concept of "middle level management." This is based on the assumption that existing management structures will not support a large-scale evacuation and that a new level of governmental management not currently found in the country is needed (Harker and Wilmore, 1982; 1979; Wilmore and Harker, 1981a; 1981b). This concept suggests forming over 100 new planning zones that would be intermediate links between state and municipal governments. The assumptions on which this new concept of governance are based were never supported by either theoretical or empirical observations. In fact, the immense literature on organizations in disasters suggests that when a void in management does exist, groups will emerge to fill this void. Thus, building on unfounded and, perhaps, erroneous assumptions, an elaborate management scheme is developed with supporting planning guidance and examples.

Other normative work on management structure has been conducted for response systems. The National Academy of Public Administration (1980) evaluated alternative organizational structures to manage nuclear power plant emergencies. A number of planning guides for various hazards also contain numerous suggestions for a management structure.

5.2.2 Coordination and Maintenance of Evacuation Support

One of the most problematic aspects of any part of emergency response is the coordination of activities of various emergency personnel. Coordination is sometimes confused with control. Coordination can be created but not imposed by a central authority (Quarantelli, 1986). By nature, coordination is activity accomplished through cooperation, not by mandate. Furthermore, it is also confused with communications. Although communications is an important part of coordination, the ability to exchange information does not guarantee a coordinated response. General principles that both facilitate and undermine coordination are fairly well-defined and understood (Mileti et al. 1985; Sorensen et al., 1984). Simply stated, coordination seems to be maximized when organizations know what they and other organizations are supposed to do in an emergency, know who is to do it, have designated and understood communication ties to others in the network, and maintain flexibility.

The inability to coordinate the management of an evacuation has been documented as a cause of poor evacuation response (Forrest, 1979; Chiu et al., 1983). The lack of communications among officials may delay an evacuation and create confusion (Quarantelli, 1983). Coordination is usually more problematic in unanticipated and rare events (Hart et al., 1985; Sorensen, 1986a).

Coordination becomes more difficult when multiple jurisdictions are involved in an evacuation. Cutter (1984) notes that interstate coordination is more difficult to achieve than intercity coordination. In Hurricane Elena it was noted that contiguous counties failed to coordinate reentry into the evacuated area (Pinellas County, 1986). Evacuation orders in that same event were not coordinated between state and local agencies, leading to confusion over which areas should evacuate

(Baker, 1986). A Governor's order' prevented a local government's critical workers from getting through roadblocks to perform their emergency duties (Pinellas County, 1986). Other examples of similar coordination problems are found in the literature.

The structure of interagency information flows during emergencies has been extensively documented in a study of search and rescue operations (Drabek et al., 1981). Often this involves the participation of emergent groups. These groups, however, are often outside the communication network of normal emergency organizations, and coordination is difficult to achieve (Quarantelli, 1986). In addition, information often enters an organization at a point where proper dissemination to all relevant officials is not accomplished. Information flows often have a factual and a perceptual structure (e.g., credibility of the information source). A variety of factors color the way organizations use and process information in an evacuation situation. For example, the lack of visual cues of an impending hazard makes it difficult to initiate communication and decision processes that would lead to an evacuation (Scanlon et al., 1976).

Implementation guidelines for establishing emergency coordination have been defined in fairly mechanistic and physical terms. For example, good information exists on how to establish the hardware of a communications system and maintain that system. It is also well documented that redundant communication systems are often needed. This type of knowledge forms the basis for developing coordination plans. Less is known, however, about efficient management and use of a communication system or promoting good interpersonal relationships in an emergency. This type of information, also important to coordination, is not often reflected in planning.

Many studies have extensively documented communication problems in evacuations (Quarantelli, 1980; Mileti et al., 1985). In contrast, few if any attempts have been made to incorporate this knowledge into practical guidance that could minimize coordination problems, except in the context of general planning guides.

Maintenance of emergency services in an evacuation has been raised as an issue for several hazard situations. One of the more persistent issues concerns role strain, conflict, and abandonment among emergency workers. Although this issue cannot be excluded as a potential problem in every evacuation situation, research suggests that it has not been a problem in previous evacuations (Quarantelli, no date; Mileti, 1985). Furthermore, ways in which role conflict can be minimized are known. For example, one nuclear power plant has designed a tracking and message exchange center which allows emergency workers to communicate with families.

5.2.3 Decision Making

To date no study has systematically examined evacuation decision-making across a range of events. Despite this gap, a fair amount of research has documented decision issues in various historical evacuations. In addition, research on hypothetical decisions has been conducted for nuclear power plant accidents (Jaske, 1984; Aldrich et al, 1982; 1978; 1979), hurricanes (Baker, 1984b), earthquakes (Mileti, et al., 1981) and nuclear crises (Brown, 1975). A recent report attempts to synthesize the process of evacuation decision making and characterize the uncertainties encountered in previous evacuations (Mileti et al., 1985). This study induces four general categories and nineteen specific uncertainties that constrain evacuation decisions of public officials within emergency organizations. These categories are

1. Problems of interpretation including difficulties in recognizing a hazardous event, recognizing the consequences of likelihood of an event, or defining the magnitude of the event and failure to define an evacuation role, recognize relevant information, or define appropriate authority.

2. Problems of communication including not knowing whom to notify, not having the ability to describe the hazard, not having the ability to physically communicate, and receiving conflicting information.

3. Problems of misperceived impacts of a decision including panic, looting or other adverse consequences, loss of job, or other negative personal impacts, such as monetary costs of evacuating and liability.

4. Problems of exogenous influences including time availability, evacuation feasibility, prior experiences, planning, and outside pressures or expectations.

The study concludes that, while we can conceptualize the general decision processes in an impending disaster, our knowledge of the factors that influence decisions in any given situation are not well understood.

Despite the lack of empirical findings concerning decision making, a variety of prescriptive decision tools or aids have been developed to automate or assist evacuation decision making (Carroll, 1985; 1983). One type of aid that is being developed is a computerized information system. FEMA has developed the Integrated Emergency Management Information System (IEMIS) for nuclear power plant application (Jaske, 1984; 1986). This system provides the user with information on population, road networks, and environmental features. In addition, through the use of an atmospheric dispersion model, a hazard impact model, a traffic flow model, and a siren sound propagation model, the planner can simulate or model a real emergency. The information outputs can be used to predict needed evacuation zones and locations of potential traffic problems. The system requires considerable input data and computer capacity. A similar system for a microcomputer has also been developed which incorporates

heuristic decision aids (Belardo et al., 1983; Seagle et al., 1985). The Sullivans (1985) describe a concept for a simulation model to test evacuation planning effectiveness.

Several decision models have been developed to assist local decision-makers in issuing evacuation recommendations when a hurricane is approaching (Simpson et al., 1985; Ruch, 1985; Berke and Ruch, 1985; Berke et al., 1985). These systems are designed to provide a recommended action to the user. The Simpson et al. approach is geared to using probabilistic estimates of landfall and confidence intervals to arrive at a decision. The Ruch (1985) model, "ESTED," allows the selection of worst-case assumption regarding possible inundation and storm-timing to arrive at a decision about when to recommend action based on expected storm arrival. Berke and Ruch (1985) provide a computer simulation model oriented to more general mitigation planning including evacuation. These systems, however, are largely untested in real applications. The extent to which local decision makers would use this latter type of decision aid is not at all clear. In Hurricane Elena, Baker (1986) found that few local emergency officials used computerized decision tools even though they were available. The diffusion of computer equipment into local government agencies may eventually offset this response if applications for emergency management are adopted.

5.3 TRAFFIC CONTROL

In the context of evacuation planning, the topic of traffic control has received little special research attention. This is likely attributed to the fact that the principles and logistics of traffic control are well established for non-emergency operations of law enforcement agencies. Furthermore, traffic control has not created problems or been a noticeable issue in historical evacuations (Quarantelli, 1980). In most instances, people are moved without traffic accidents or congestion. Quarantelli (1983) noted in a study of the Taft, Louisiana, evacuation that there was no traffic congestion during the rapid evacuation of 17,000 people in spite of darkness and rain. Nevertheless, traffic control has been raised as an issue for crisis evacuations and nuclear power plant emergencies.

Traffic accident rates in 54 evacuations were studied by Hans and Sell (1974). They concluded that populations can be evacuated with minimum deaths and injuries. In that study, accident rates were calculated to be lower during evacuations than during normal times. Bastien et al. (1985) added data to Hans and Sell's data and calculated the probability of death and injury ($2^{-3} \times 10^{-9}$ for deaths; $3^{-4} \times 10^{-8}$ for injuries). These rates, however, are suspect because of problems with the original data. In two recent evacuations involving the movement of large populations (TMI, 1979 with 170,000 people; Mississauga, 1979 with 225,000 people), no traffic deaths were recorded, and no significant injuries due to accidents were reported. In a study of evacuations from chemical accidents over a five-year period, no traffic injuries or

fatalities were reported to be associated with any of 59 evacuations (Sorensen, 1986b).

This is not to imply that traffic-control problems never occur. Anecdotal evidence that traffic does get congested has been reported in media accounts, although it is more usual after an event than during evacuation. At Mount St. Helens, it was noted that the convergence of sightseers led to traffic congestion (Foxworthy and Hill, 1982). Furthermore, official roadblocks used to prevent entry into evacuated areas were a problem to the staff and were often avoided by those moving into the closed zones (Sorensen, 1981; Foxworthy and Hill, 1982). In general, reentry guidelines have been found to be inadequate for controlling the movement of people back into an evacuated area (Burton, 1981; Moore et al., 1964; Quarantelli, 1980)

Research on transportation systems planning, other than evacuation time modeling, has been mainly conducted to support crisis relocation planning. This work may be useful for evacuation planning for other hazards. Systan, Incorporated, has conducted extensive work on the logistics of traffic control in evacuations (Billheimer et al., 1976). This work concludes that an average large-scale evacuation will not be limited by fuel supply or vehicle availability. Inefficient allocation of fuel and vehicle, however, will likely cause localized problems. This work also suggests that the major problem in a large-scale evacuation is sharply peaked travel departures which may cause bottlenecks and traffic jams. Ways to even the flow have been explored but remain untested. A comprehensive report has been prepared for FEMA which details traffic control problems, control options for dealing with problems, and implementation guidance (Billheimer and McNally, 1983).

Much of this research is summarized in a recent FEMA planning guide--"Transportation Planning Guidelines for Evacuation of Large Populations" (USFEMA, 1984d). This guide will be of use to emergency planners in large urban areas who must plan for disasters other than a nuclear crisis. For the most part, the guide is reflective of the general aspects of evacuation planning for hurricanes and nuclear power plant accidents. One major difference, however, is that the guide assumes that people can be assigned to a certain destination or host area. Research to date suggests this is not a sound planning principle and potentially misleading. Other aspects of the guide remain somewhat speculative. For example, the viability of scheduling departures, freeway reversal, and entry permits remain largely untested and lack critical evaluation.

5.4 WARNING SYSTEMS TO SUPPORT EVACUATION

Although this study cannot go into great depth on the subject of warning systems, they are an integral component of the evacuation process. As a result, this section only attempts to summarize some of the general research findings which can enhance the issuance of warnings to support an efficient and effective evacuation (Mileti and Sorensen, in

press; Sorensen, 1984a; 1982). In addition to the factors discussed, a variety of social and psychological factors influence the ways in which warnings are interpreted (Sims and Baumann, 1972; Mileti, 1975). Inadequate or poor warnings are a documented cause of fatalities and injuries in many disasters. Warnings are also supported by public education and information programs (Farace, 1975; Farr, 1980; Farr and Rosenthal, 1975).

Ten factors have been documented as being important to issuance of a good warning. First is the source of the information. Emergency public information or warnings that are credible and reliable are more likely to stimulate evacuation. People have different views about the credibility of others' and any one source will not be perceived as credible by an entire population. A warning message which contains endorsements by a mix of scientists, organizations, and officials is more likely to be considered credible.

Second, a warning message is more effective if it is consistent. Inconsistency in the tone or information in a message creates confusion and uncertainty among recipients (Segaloff, 1961). Message consistency is important. For example, a message stating that something bad is happening but there is no cause for concern is much less effective than a message that tells people how concerned they should be in light of the situation.

Consistency among multiple warnings is also a determinant of understanding and belief. In a study of the Rio Grande Flood, Clifford (1956) found that inconsistent information caused confusion, and, as a result, people were less likely to understand or believe that a flood was going to occur. Fritz (1957) reached the same conclusion in a study of warning responses to a wide range of disasters.

Third, accuracy of the information also affects understanding and belief. For example, Mileti et al. (1975) state that past errors in disaster warnings can cause people to doubt subsequent warnings.

Fourth, the clarity of the emergency information is important. A warning message in simple language that can be understood is more effective because people are more likely to know what is happening and what they should do about the situation. An unclear message can cause people to misunderstand or ignore it.

Fifth, a message that conveys a high level of certainty about the events taking place and the protective actions people should take is more effective than a tentative one. Even if there is a low-probability or ambiguous situation, the messages can vary in their level of certainty (even about the ambiguity). Certainty determines the level of belief in a warning and affects decision making. In a study of response to earthquake prediction, it was found that warnings become more believable as the probabilities attached to them become greater (Mileti et al., 1981). If warnings are certain, people are more likely to evacuate.

Sixth, the level of detailed information in a message influences evacuation decisions. Insufficient information creates confusion, uncertainty, and anxiety. If messages contain insufficient information, the public's response is to fill the information void. This can promote rumors or uninformed misperceptions or fears. The amount of information provided affects understanding, personalization, and decision-making. A study of family response to hurricane and flood warnings conducted at the University of Minnesota found that general and vague warnings caused people not to take protective actions (Leik et al., 1981). In a study of response to the Mount St. Helens's eruption, it was found that more detailed information led to higher levels of perceived risk, which, in turn, resulted in protective actions being taken (Perry et al., 1982b).

Seventh, messages containing clear guidance about protective actions people should take and the time available for doing so are more effective than messages that provide no specific instructions. Guidance is often necessary to encourage people to take the proper action. A study of the Big Thompson Canyon Flood (Gruntfest, 1977) found that people who received warnings during the flood were not necessarily advised what to do. As a consequence, many who were warned attempted to drive out of the canyon and were killed.

Eighth, the frequency of public messages influences evacuation behavior. People frequently do not evacuate after hearing one warning. Frequent messages can reduce the anxiety of waiting to confirm what is happening or to learn more details, thus, reducing the effect of misinformation and misperceptions. Frequency affects hearing, understanding, believing, and deciding and is, thus, important at most stages of response. Numerous studies underscore the importance of repeated hearing of a warning as a condition for response.

Ninth,it is imperative that the specific location of the event be included in the message. Emergency warning information that clearly states the areas affected or those that may be affected by the event is most effective. Identifying a location is important in believing and personalizing a warning. For example, Diggory (1956) found that the greater the proximity to a threatened area, the greater the possibility that a message will be believed. Other studies show that more location-specific messages lead to greater levels of personalized risk (Perry and Greene, 1983).

Tenth, the channel of information plays an important role in warning response. Effective warnings use a range of possible channels instead of a single channel, thereby reaching as many people as possible in a short amount of time. Moreover, some channels appear to be more effective than others. Generally, personal communications, rather than media or siren warnings, more effectively persuade people to evacuate rapidly (Mileti, 1975; Gruntfest, 1977).

5.5 EVACUATION STRATEGIES

The feasibility of using pre-planned evacuation strategies has been challenged by evacuation planning critics (see Chapter 2). The strategies subject to question include selective evacuation, time-phased evacuation, and evacuation to designated host areas. Selective evacuation is based on estimated threats from the expected event and involves evacuating only certain pre-determined zones within larger risk areas. Time-phased evacuation involves a delineation of risk zones to be evacuated sequentially over time. Other evacuation strategies may involve selective evacuations based on demographic factors (e.g., the elderly, pregnant women) or other criteria (e.g., non-essential workers, people with respiratory problems). Evacuation to designated host areas involves ordering groups to move to a specified location or area.

Another relevant aspect of evacuation strategy (once a decision to evacuate has been reached) concerns the timing of public notification. Pre-planned strategies may include early warning to insure sufficient time to take action or delayed warning to avoid public complacency.

Research on the efficiency and feasibility of these strategies is rather scant, and anecdotal evidence provides no clear answers. For example, time-phased evacuation has been used to move people when estimated risks have increased over time, not as a strategy to increase the efficiency of loading evacuation routes. Thus, a case like Mississauga does not prove the viability of time-phasing; it only suggests that, when sequencing is based on a logical development of events, people will follow time-phased evacuation orders.

Anecdotal evidence concerning zonal evacuation provides a somewhat stronger case for this strategy's viability. For example, during Hurricane Alicia, only selected communities and parts of communities were issued evacuation notices. In Galveston, Texas, these selected areas had much higher evacuation rates than the areas that were not advised to evacuate (Savage et al., 1984). Zonal evacuation should be based on understandable boundaries. Baker, (1986) observed that ordering evacuation of only part of a county was confusing to the public. Selected zonal evacuation may be appropriate for hazards such as earthquakes that could create a threat to areas below reservoirs, to unstable slopes, or to unstable buildings (Panel on the Public Policy Implications of Earthquake Prediction, 1975).

At TMI, however, selective evacuation based on demographic criteria, which targeted groups such as pregnant women and pre-school children for evacuation, resulted in many others leaving as well--probably because basically the recommendation did not conform with people's perceptions of the risks. Young (1954) observed that a selective evacuation strategy that requires women and children to leave first is not as effective as a strategy that will keep the family together. The fact that people evacuate as family units has since been well established (Drabek, 1969).

Directing selective movements of geographically differentiated areas to a specific host area or collection center may also be problematic. Young (1954) observed that many people chose to evacuate to the homes of relatives and that this choice was more likely if the distance to the relative's home was not too great. Patterns of evacuee destinations have been well documented, although the distances travelled are less well known.

Thus, research suggests that evacuation strategies must conform both to scientifically defined explanations and to publicly defined logic.

5.6 EVACUATION MODELING

Quantitative traffic models are used to estimate the time required for populations to evacuate to safer areas. These estimates are an integral part of hurricane evacuation planning, a regulatory requirement for nuclear power plant planning, and they are also included in crisis evacuation planning. In addition, models have been developed to simulate the evacuation of buildings (Kisko and Francis, 1983). These models have had little or no application to other types of evacuation planning in the research literature.

A range of approaches have been used to develop models and time estimates. One of the simplest is an aggregation procedure which assumes a vehicle load from a given region, assigns that load to routes, and estimates evacuation time by dividing number of vehicles by road capacity estimates. Variations add other variables such as delay times, etc. This approach is used in some hurricane evacuation planning efforts (Ruch, 1981; Ruch, 1983; Stone; 1983). This is also the basic approach used for crisis relocation planning (Dike et al., 1964; Schmidt, 1970; Strope and Henderson, 1978; Stope et al., 1976; USFEMA, 1984d), and in early reactor accident studies (Aldrich et al., 1978; 1979).

A more sophisticated modeling effort was developed for the NRC to evaluate evacuation time estimates that are presented as part of Final Safety Analysis Reports (FSARs) (McClean et al., 1983; Moeller et al., 1982; Urbanik, 1981; Urbanik et al., 1980). This model is referred to as the CLEAR model (Calculates Logical Evacuation and Response). CLEAR simulates vehicle departures and movement on a network, given conditions of traffic volumes and flow (e.g., handling vehicles at intersections, queuing delays, and varying travel velocities). Assumptions concerning the time required to prepare for departure can also be manipulated. CLEAR outputs include vehicle position at any point in time, vehicle population in given zones, and time requirements for clearing each zone. CLEAR requires input data on population distribution, the transportation network, and the specification of some assumptions.

The most sophisticated evacuation time models reviewed were I-DYNEV (USFEMA, 1984c) and NETVACI (Sheffi et al., 1982). These models incorporate a traffic simulation model with a traffic assignment model (Dangermond, 1985). The latter model identifies the best traffic routes

for vehicles to follow out of the EPZ. The simulation model follows vehicles traveling on the road network and replicates the dynamics of the flow. I-DYNEV allows vehicles to travel alternative routes due to congestion, and it tracks vehicle movement on each network link. In addition, the model incorporates turn movements by accounting for traffic discharge and loadings at each intersection. The model requires data on the roadway system, traffic controls (e.g., traffic lights), vehicle demographics, and assumptions concerning trip generation. I-DYNEV is flexible in that it allows users to study special problems including selective evacuation strategies, bad weather, travel conditions, emergency traffic control, possible traffic obstructions, and alternative trip generation scheduling.

Another sophisticated evacuation traffic model is MASSVAC (Hobeika and Jamei, 1985). It is similar to I-DYNEV, except that it allows movement away from an area instead of a point. Thus, it is useful in simulating evacuation away from a coast or out of a flood plain. In addition, it allows the designation of shelter locations and simulates and tracks arrival at the shelter.

Tweedie et al. (1986) describe the process of preparing a traffic time estimate in a comprehensive fashion, irrespective of what model is used. They provide details on collecting population data from the area at risk, establishing assumptions, formulating the model, and calculating clearance times. Estimates are developed for different weather conditions and four different times of day. Walsh et al. (1983) describe a procedure for incorporating population projections into traffic-time modelling to predict evacuation times under future land-use conditions and population densities.

Few efforts at comparing models and results have been undertaken. CLEAR results have been compared to results of other traffic time estimates for the Beaver Valley, Pennsylvania, nuclear site, but bases for differences are not rigorously analyzed (Moeller et al., 1982). In addition, CLEAR has been used to predict observed traffic flow along freeways (Derosiers et al., 1984). Results indicate a close fit under certain conditions but not under others. A major deficiency of research in this area is the lack of comparative studies and model validation. Baker (1986) observed that the time required to clear Tampa Bay during Hurricane Elena was much less than estimated. In other areas such as the Florida Panhandle, the estimates were fairly accurate.

Assumptions of these models have been heavily criticized as discussed in Chapter 2. Little research has been conducted to validate model assumptions under actual evacuation conditions. For example, traffic flow speeds and road capacities under evacuation conditions are largely unknown (USFEMA, 1984d). Behavioral studies are used to develop some model assumptions such as destinations, departure delays, and number of vehicles used (Ruch, 1983; 1981). However, the behavioral intentions used by Ruch likely do not resemble actual emergency behavior. Few comparisons of intended behavior to actual behavior have been undertaken. Moreover, behavioral data collected after evacuations have not provided

the details necessary for model validation. Models usually treat trip origins as input data, based on field counts of daytime and nighttime population. Recently Glickman (1986) has developed a model to estimate time-of-day variations in total population within various urban environments.

Brand (1984) provides a detailed critique of assumptions used in estimating the time required to evacuate New York City under crisis conditions (Strope and Henderson, 1978). Brand's analysis suggests that, instead of taking two days to evacuate New York City as estimated by Strope and Henderson, it would take closer to two weeks. It seems that what the two studies actually accomplish is to band the problem with high and low estimates. The actual time, which may be somewhat irrelevant to developing evacuation plans, likely falls between the optimistic and pessimistic cases.

5.7 SPECIAL POPULATIONS

Special populations include those people whose needs may not be met by general evacuation planning. A fairly comprehensive listing of special populations, modified from Lindell et al. (1985), is provided in Table 5-1. These populations may be special due to location or population attributes, and they may be concentrated or dispersed. For example, institutional populations, such as people in prisons, hospitals, nursing homes, day care centers, schools, or nurseries, may present certain evacuation problems because of their concentration. Others, such as non-ambulatory, deaf, mentally retarded, or foreign-speaking persons may be dispersed throughout a risk area, which creates different problems. Some special groups may possess characteristics of both. In a tourist area, hotels may concentrate people needing special evacuation attention (e.g., foreigners who do not understand English).

The problems that lead to special evacuation planning vary by group. Some may need more warning time because it takes longer to mobilize and move. Others may not be able to hear the warning. Some may lack transportation to evacuate. Others may need special assistance in moving. Still others may require special medical attention during and after the evacuation.

Very little research has been conducted on the process of and problems encountered in evacuating institutionalized populations (Quarantelli, 1980). Perhaps the best documentation of time and resources needed to evacuate hospitals and nursing homes comes from the Mississauga evacuation (Burton, 1981). A chlorine spill made it necessary to evacuate three hospitals and six nursing homes. No major problems arose to prevent the evacuation, but some issues still surfaced.

Pinellas County (1986) extensively documented its experience with evacuating special populations during Hurricane Elena. Three hospitals (211 patients) and 19 nursing homes (1,860 residents) were moved. The largest hospital with 116 patients took 5 hours to evacuate. The average

time to complete an evacuation of a nursing home was 6 hours. The hospitals were evacuated using five regular and nine wheelchair-lift buses.

Several problems were identified from this experience:

1. these facilities were not given an early warning,
2. transportation from the nursing homes was inadequately coordinated at times,
3. buses frequently arrived late as a result, and
4. some buses designated for use in evacuating nursing homes were diverted by law enforcement officers for other uses.

In addition, local television stations did not use visual text to warn the hearing-impaired. Despite a system to preregister people with special needs, many who had not registered called the 911 number or other agencies (often more than one), to request evacuation assistance. As a result, many of them had already left when ambulances arrived to assist them.

There is a debate about including the elderly as a special group that would need additional evacuation planning and assistance. Some would argue that the elderly already have support structures and do not need special assistance. Others also conclude that the elderly are just as likely to hear warnings as are others (Hutton, 1976). On the other hand, researchers have found that the elderly are at a disadvantage during emergencies and that they require medical assistance during the evacuation period (Pinellas County, 1986).

Special evacuation planning is often needed for other types of facilities. Industrial facilities could possible move inventories or equipment to avoid damages. Commercial establishments could have customers to evacuate. The lack of planning for these types of facilities is noted in the literature. Anderson (1970) discussed the problems encountered by a car dealer during the Cresent City, California, tsunamis. Sorensen (1986a) identified a problem in warning people in movie theaters and shopping centers during the Cheyenne, Wyoming, flash flood.

People with pets are beginning to be noticed as a special planning group. The experience at Mississauga identified pets as a problem (Burton, 1981). People who left pets behind wanted to return to care for and feed them. People who take pets with them frequently will not be allowed into shelters. At least one evacuation plan has explicitly addressed the problem by arranging a pet care center outside the risk area for Shoreham Nuclear Power Plant.

Some issues are addressed in the context of crisis relocation planning, such as medical problems or prisons, which have broader applicability to evacuations for other types of hazards. The potential medical problems in a large-scale evacuation have been identified but not fully resolved (Lancy et al., 1976; Geiger, 1984). Evacuation problems associated with relocation of minorities (National Capitol Systems, 1981)

and prisons and other penal institutions have received brief research attention (Steen and Ryland, 1982; Ryland and Enns, 1976). The former study identified three options for movement of prisoners including dismissal of low risk prisoners, movement to other prison facilities, or movement to improvised facilities. Pinellas County (1986) found that, while they had national guard troops to support the movement of prisoners if needed, they could not find any adequate facilities, given the short time frame.

A study is currently underway to look at generic evacuation planning issues in schools and how to address those issues (Gant and Adler, 1985). Sorensen (1986b) identified a number of schools that were evacuated due to chemical accidents and found that a variety of strategies were successfully used:

1. Students were dismissed early to walk home.

2. Early dismissal was supported by calling for buses to take children home.

3. Children were bused to another facility and were taken home after school or were picked up by parents.

4. Parents were permitted to pick children up at school and those remaining were transported home.

The strategy that works best seems to be determined by the nature of the problem and the local practices and customs.

Evacuation research to support planning for geographically dispersed groups is also scant. Problems of foreign-language and minority populations have been extensively researched (Perry and Greene, 1982b; Perry and Mushkatel, 1984; Nigg, 1985); however, problems still exist with implementing the findings of this research. For example, hurricane evacuation planners in certain regions of Florida have only recently acknowledged that Spanish-speaking persons required warnings. Prior to Hurricane Iwa, officials had difficulty warning non-English speaking people (Chiu et al., 1983).

Tourists are another special population which may require special planning. In the 1981 Hurricane Iwa in the Hawaiian Islands, local officials had problems deciding how to warn the tourists (Chiu et al., 1983). There has been very little research on evacuating tourist areas such as beach communities, resorts, or cities with large seasonal tourist populations.

Evacuation planning research on other types of institutions and populations identified in Table 5.1 is less well-developed. Improvements in research on evacuation problems for most types of special populations are needed. In addition, more work is necessary to provide adequate planning guidance.

Table 5.1. Facilities and populations with special planning needs

Facilities
Health related
Hospitals
Nursing homes
Halfway house (drug, alcohol, mental health)
Mental health institution
Retirement communities
Penal
Jails
Prisons
Detention camps
Reformatories
Assembly and athletic
Auditoriums
Exhibition halls
Gymnasiums
Stadiums
Amusement and recreation
Beaches
Campgrounds
Conference centers
Amusement parks
Parks and natural areas
Golf courses
Ski areas
Community recreation centers
Marinas
Movie theaters and drive-ins
Educational
Day care centers
Preschools
Schools
Specialty schools
Colleges

Table 5.1. (continued)

Religious
Places of worship
Group centers
Residential
Hotels/motels
Apartments/condominiums
Mobile home parks
Dormitories
Transport
River/lake
Dam locks
Terminals (air/train/bus/ferry)
Rest areas
Roads
Commercial/industrial
Shopping centers/stores
Downtown business districts
Industrial parks & buildings
Restaurants
Office buildings
Populations
Mentally handicapped
Mobility impaired
Hearing impaired
Visually impaired
Elderly
Tourists
Foreign language speaking

(Modified from Lindell et al. 1985)

5.8 SHELTERING

Sheltering has been divided into four categories: emergency shelters, temporary shelters, temporary housing, and permanent housing (Quarantelli, 1982b). The categories differ with respect to the time inhabited, permanency, and resources to support evacuees. These four types are refuges for evacuees and not shelters to protect populations from disaster effects. Shelter in the context of evacuation primarily refers to the first two types which provide temporary residences for evacuees.

Shelter has been a direct topic of only a modest amount of research, more has been done in the context of a broader disaster study. Several specific case studies of sheltering processes have also been conducted (Klausner and Kincaid, 1956; Quarantelli, 1982b). Consequently our knowledge about sheltering is generally limited to case studies, particularly as it constrains evacuation logistics.

For small-scale evacuation, there is no evidence that sheltering is a significant constraint to evacuation. In fact, most studies observe that sheltering capacities are greater than demand (Drabek, 1969; Cutter and Barnes, 1982). An exception was that, during Hurricane Alicia, it was observed that the lack of sheltering off Galveston Island likely prevented some people from evacuating, although the impact was not measurable (Savage et al., 1984). At times, demands on individual shelters may exceed capacity. People may arrive at shelters before they are opened or go to shelters to which they were not assigned (Pinellas County, 1986). In addition, anecdotes of shelter problems abound. These include lack of food, lack of beds, poor management and operations, poor access to information, inadequate sanitary facilities, lack of heating and cooling, lack of health care, interpersonal problems, and so forth. Yet such hardships are usually endured without great difficulties or losses.

At a pragmatic level, such problems do not occur because of a lack of knowledge regarding sheltering but because of a lack of planning, inadequate resources, or poor implementation. It is likely that sheltering efficiency and efficacy could still be marginally improved by a better understanding of shelter use and management. This has been largely accomplished by building on previous experience and revising practices on the basis of incremental learning (Forrest, 1979).

Demand for shelter by evacuees is fairly well documented. Rarely does more than 15 to 30% of an evacuating population use an official shelter--most people stay with friends, relatives, or at a motel. One exception was that 40% of the Hurricane Elena evacuees used an official shelter. No good explanation for this anomaly has been found.

While this study cannot cover the topic of protective shelter, it should be noted that evacuation does involve movement to a protective shelter and that sheltering is often an alternative to long-distance

evacuations. Issues associated with protective shelter include availability, identification, ability to establish safety, crowding, and resource availability.

Although sheltering on a small scale may not be highly problematic, it is unclear whether such experiences can be used to generalize large-scale evacuations of cities. Research has been conducted on sheltering requirements in the context of CRP. Aspects studied include food for evacuees (Billheimer and McNally, 1982; Billheimer et al., 1975), shelter management (Chenault and Davis, 1975), construction of shelters (Wichham and Tidemann, 1978), and shelter availability (White, 1975). Such research has been translated into planning guidance for host areas (USDCPA, 1979b).

It is fairly clear from this research that it is possible to understand shelter needs for a given level of evacuees. Uncertainties that remain still include how many evacuees would need shelter, where people would go, and what level of resources could be provided. For example, research would suggest that under certain assumptions it would not be possible to adequately shelter populations in rural areas. Despite the fact that planners could estimate what is needed, distribution systems would not be adequate. Platt (1983) has carefully researched sheltering resource requirements for a crisis relocation to a host area and has concluded the resources would be inadequate to support the relocated population.

An aspect of shelter management and evacuation planning that is just beginning to receive attention concerns the psychological impacts of the evacuation/sheltering experience (Bolin, 1985; Quarantelli, 1985b) and the provision of psychological services (Sowder, 1985). Psychological problems have been noted to be more of concern in large-scale, long-term relocations following a severe disaster. Children may be particularly vulnerable (Bolin, 1985; Redlener, 1984). Evacuees who have experienced life-threatening circumstances or have lost kin or friends may also be susceptible to mental health problems (Bolin, 1985).

5.9 EVACUATION COST

The total cost of evacuations conducted yearly in the United States are unknown for several reasons. First, we have a poor accounting of all evacuations and their dimensions. Second, difficulty exists in identifying and aggregating all costs including secondary ones. Third, identifying the benefits of evacuation presents another difficult problem. Finally, the costs of damages caused by a disaster are difficult to determine.

Several evacuations that involved little or no physical damage have been studied to determine evacuation costs. These include the TMI evacuation (Flynn and Chalmers, 1980) and the Mississauga evacuation (Burton, 1981). For TMI, the direct and indirect costs to evacuating families have been estimated using survey data. On the average, the estimated cost to an evacuating family was about $300; and the cost to a

nonevacuating family was about $40 (Flynn and Chalmers, 1980). The actual evacuation cost was about $200, with the remainder representing lost income. Given a median length of stay for evacuees, the average daily expense per family was about $40. Only 20% of the evacuees reported a pay loss which averaged $500. Overall Flynn and Chalmers estimated the total cost of the TMI accident to families within a 15-mile radius to be $18 million.

Direct costs to business and industry have also been estimated by the State of Pennsylvania. Business losses during the week following the accident have been estimated at $106 million which translates into an income loss of between $10 and $14 million (Flynn and Chalmers, 1980). Estimates of the amount of that loss that was offset after the accident or the indirect or secondary impacts that occurred are almost impossible to estimate.

Cost estimates were made in a similar manner for the Mississauga evacuation (Burton, 1981). The average estimated cost of the evacuation to a household was $220, plus $90 in lost wages. Average duration of the stay was three days. Taking into account the difference in the value of Canadian currency, the average daily cost of the evacuation was about $58 (U.S.). Total direct costs were estimated at $17 million (Canadian) with an additional income loss of $8 million (Canadian). About 27% of the evacuees reported income loss. Thus the average loss per household for those reporting was about $450 (Canadian). Loss of business income was estimated at $50 million. The Mississauga study also provides some breakdown on costs. Travel averaged 12% of the total cost, accommodations about 20%, additional food expense about 38%, and miscellaneous expenses about 30%.

If we compare the two evacuations, we find very similar cost estimates, particularly if duration and fixed costs are taken into account. From these results the direct cost of evacuation expenses could be estimated at about $25 for transportation plus another $40 per day the family remains evacuated. Indirect loss such as wages and business loss including secondary impacts are more uncertain and will likely vary according to location and circumstance.

Comparable estimates for hurricane, floods, or other natural disasters are not readily available. Some estimates have been prepared for the costs of false alarms for hurricane evacuations, but the estimates are largely speculative (Baker, 1985). Economic investigations of disasters have focused on direct damage rather than on emergency response costs to evacuees or emergency organizations (Cochrane, 1975).

5.10 RELOCATION AS EVACUATION

The relationship between temporary evacuation and permanent relocation due to risk and disaster has been explored at a theoretical level (Aquirre, 1983). Many of the social processes associated with evacuations may parallel population mobility in general. Empirical studies to date on post-disaster impacts have not really captured relocation

processes as they have looked at larger social aggregates. Motz (1983) has developed a social psychological framework for investigating the social impacts of relocation, but this has not been applied to a disaster-induced relocation. Recently Quarantelli (1985a) has provided a conceptualization of relocation to distinguish it from evacuation. In this paper, he distinguishes relocation from evacuation as being a single-direction move without a return trip. It is also a movement of a way of life, not just people. Furthermore, Quarantelli characterizes it as a difficult process that is appropriate only in rare circumstances, has numerous institutional and political obstacles, and can only be undertaken in a manner compatible with the group being moved.

Several studies have investigated the relationships between warnings, emergencies, and mobility decision making (Kielcolt and Nigg, 1982, Goldhaber et al., 1981). The former concluded that increased earthquake threat in Southern California was not a salient dimension of mobility decisions. While people may be aware of the threat, the existence of an ambiguous threat does not lead to relocation. This finding is supported by Mileti et al. (1981). Likewise Goldhaber found that the TMI accident did not play a major role in mobility decisions after the event.

Fowlkes and Miller (1982) investigated relocation as part of a larger survey of victims of the Love Canal, New York, hazardous waste dump incident. The major issues during that incident were trust of public officials (regarding the extent of the problem) and the competence of government agencies (regarding adequate handling of the situation). The relocation process was stressful for those involved, particularly because decisions and settlements took a long time. A similar set of problems was encountered at Times Beach, Missouri, following the discovery of dioxin.

Perry and Mushkatel (1984) investigated the relocation of an entire community to avoid a flood hazard. Their findings, summarized in the previous chapter, parallel those for other types of relocation (e.g., for reservoir and highway construction). From this case study, principles for positive relocation planning are developed. First, the community to be relocated should be organized. Second, citizens should be involved in the decision making at an early stage of the process. Third, social and personal needs including the preservation of social ties and networks are important considerations. Fourth, citizens must be made aware of the political processes involved and that political support is necessary for a successful relocation. Fifth, conflicts should be expected and openly dealt with when they occur.

Thus, relocation appears to be a more complex problem in some ways than evacuation. The extended time frame, large expenditures of resources required, increased opportunity for political involvement, and greater social impacts help differentiate relocation from evacuation. The research to date on relocation does not provide a strong body of knowledge on which to develop improved planning. Further case studies and systematic investigations of relocations would improve that knowledge.

6. RESOLVING THE ISSUES

6.1 INTRODUCTION

6.1.1 Approach

This chapter addresses the issues raised in Chapter 2 in light of the policy and planning for evacuations discussed in Chapter 3 and the behavioral and planning research findings presented in Chapters 4 and 5. These are addressed, first, as general multihazard evacuation issues and, second, as hazard-specific issues unique to a particular hazardous event. These issues are summarized in Table 6.1. In comparing issues to research findings, conclusions are reached on (1) whether an issue exists, (2) whether it has been adequately addressed by research, (3) whether the issue is valid in light of research findings, (4) whether new research will help resolve the issue, and (5) whether there is sufficient knowledge to examine existing evacuation policy on the issue.

6.1.2 Confronting Issues on Nuclear Crisis and War

Some issues concerning nuclear-war-evacuation planning are sufficiently unique that they deserve special attention. In this section these are analyzed based on existing research. Since planning for nuclear war, evacuating has been a topic of great controversy and since there is a lack of empirical evidence, a philosophy of analysis is first discussed.

Essentially, evacuation planning for nuclear war survival is a political decision. As such, the decision involves two types of planning: (1) as a part of a country's strategic defense policy and (2) as planning for citizen evacuation in a threat situation. The first involves relocation of population to provide the country with better resources for dealing with a confrontation and to protect the population in the event of a nuclear exchange. The second is planning for spontaneous or protective evacuation not linked with defensive military planning. Politically both planning postures have been in and out of favor. It is not the purpose of this study to support or reject planning on political grounds.

Planning for any type of evacuation is feasible. Evacuation can move people from high risk areas. The effectiveness of doing so varies in part with the level of planning and the availability of resources. It is probably possible to have evacuation plans that theoretically can evacuate large numbers of people in a wartime scenario. Historical evidence from England, France, and Germany points out that this can be done under certain circumstances. It is beyond our knowledge to prove that it can be done under all possible nuclear war scenarios. It should be noted, however, that even given the absence of plans or with some

Table 6.1. Summary of evacuation issues

Physical Hazard Characteristics

Uncertainty in ability to specify hazard parameters.

- Location
- Timing
- Magnitude
- Effects
- Secondary Hazards

Uncertainty in ability to detect hazards.

- Scientific ability
- Lack of physical cues

Hazard characteristics constrain evacuation effectiveness.

- Speed of onset

Planning increases the threat or risk of hazard.

- Planning increases the likelihood of an event

Warning Characteristics

Uncertainty in ability to alert.

- Lack of warning systems
- Timing of warnings
- Information withholding
- Inadequate communication
- Risk not revealed
- Warnings not issued to certain groups
- Sirens not heard

Information constrains evacuation.

- Special terminology
- Probabilistic information
- Multiple messages
- Inadequate content
- Credibility
- Frequency
- Siren use

Table 6.1. (continued)

Social Issues

Social factors color risk perceptions.

- Mitigation measures
- Prior experience
- Depersonalization of threat
- Fear of radiation
- Denial of hazard
- Denial of need for preparedness
- False alarms

Factors color the ability to receive warnings.

- Culture and ethnicity
- Disbelieve ability to detect or predict
- Lack understanding of risk

Factors affecting the ability to evacuate.

- Economic resources
- Special or institutional populations

Organizational Issues

Planning elements are inadequate.

- Coordination of planning is lacking
- Inadequate planning for shelters
- Lack of plans
- Planning for secondary hazards
- Definition of emergency planning zones (EPZ)
- Plans for institutional facilities and special populations
- Planning for reentry
- No support for planning
- Planning for emergency resources to support evacuees
- Planning for medical and health care of evacuees
- Planning for extended evacuations
- Planning uses the wrong assumptions

Training of evacuation personnel is inadequate.

The technical basis for evacuation planning is inadequate.

- Evacuation time estimates are inaccurate
- Plans will lead to unnecessary evacuation
- Organizations for developing plans are lacking
- Organizations with responsibilities downplay the hazard

Table 6.1. (continued)

The technical basis for evacuation planning is inadequate. (continued)

- Knowledge not transferrable
- Dissemination of technical knowledge is poor
- Population at risk is unknown

Response Issues

Physical factors constrain evacuation.

- Population is too dense to evacuate
- Population in areas with seasonal peaks
- Boats will interfere with island evacuation
- Traffic accidents will constrain evacuation

Public behavior.

- People will hold parties instead
- Evacuation shadow
- Panic
- Convergence
- Spontaneous evacuation
- Aberrant behavior
- People won't use specially designated routes
- Stress will occur due to evacuation
- People won't obey officials
- People won't evacuate for long periods of time
- People don't know how to evacuate
- People will shelter instead
- People will not go to designated host areas
- Total social chaos

Emergency worker behavior.

- Role abandonment
- Denial of evacuees
- Erosion of leadership
- No outside support

Evacuation not perceived as a public good.

- Evacuation puts people at greater risk
- People have right to stay
- Evacuations create liabilities

planning, people will evacuate to safer areas when or if they feel themselves unsafe. This evacuation will, as all others do, have costs. Evacuation as a protective strategy for any hazard is not a zero-risk undertaking, a guaranteed means of saving everyone at risk, nor a country-club experience.

Due to the nature of the problems posed by the hazards of nuclear war and a lack of experience on which to establish scientific evidence, we largely do not know how many people could or would evacuate, how smooth the evacuation would be, or how comfortable it would prove to be for the evacuees. Arguments of logic can be used to support varying levels of effectiveness. Reasonable hypotheses can be offered but are not provable. With this in mind, our best hypotheses are offered with the caveat that the actual outcomes are not fully known.

6.2 ISSUES CONCERNING PHYSICAL HAZARD CHARACTERISTICS

6.2.1 Uncertainty in Ability to Specify Hazard Parameters

6.2.1.1 Location, timing, magnitude, and impacts

There is little doubt that the uncertainties in specifying the nature and behavior of physical hazard (including the timing, the magnitude, the probability, and the area of impact) from events are major issues in evacuation planning. This general issue is manifested in a variety of ways for each hazard included in this study. Uncertainties seem to arise for three reasons. First, most of the physical systems that create hazards behave in a random or a stochastic way which create probabilities and uncertainties for the evacuation planner. Second, the theories and the models used to predict hazards are inadequate or fail to develop a means of accurate prediction of some threats. Third, the collection of data that could be used to obtain more accurate prediction is limited by technology or resources.

One problem that is linked to this issues is that of false alarms. While some false alarms are created by human error or equipment failure, most false alarms are likely attributable to inability to predict hazard timing, location, or magnitude, (e.g., a tsunami). A second and by far more serious problem is the failure to evacuate threatened populations. As basic and applied research on physical hazards and their causes reveals new knowledge and as that knowledge is incorporated into planning and detection, uncertainties will be removed. It is beyond the scope of this study, however, to judge what research is needed to improve hazard prediction.

6.2.1.2 Secondary and multiple hazards

Volcanoes, hurricanes, and earthquakes have multiple hazards for which evacuation is a viable component of protective action. The ability to detect and specify the nature of these hazards is critical to

effective evacuation planning; however, the current state of knowledge about the relationships among the multiple hazards and hazard effects constrains evacuation planning. These uncertainties also make it complicated to plan for the variety and range of possible contingencies that can arise. This complexity may be reduced somewhat by taking a generic approach to planning, but the links between primary and secondary hazards still need to be specified. Additional research on this issue would improve this process.

6.2.2 Uncertainty in the Ability to Detect Hazards

6.2.2.1 Scientific ability

Using evacuation as a protective action could be ineffective because the onset of some hazards is difficult to detect, let alone specify. This inability to detect hazards exists, partly, because currently available engineering expertise is not properly applied to the technology of detection and, partly, because of a lack of detection instruments. This deficiency poses serious problems when fast-moving events, such as flash floods or in dam failures, make immediate detection and population evacuation critical. For slow-moving events, this is less problematic because there will probably be adequate time to evacuate threatened populations.

6.2.2.2 Physical cues

Physical cues are important determinants of evacuation behavior. It is easier to achieve high levels of evacuation when cues are present to aid detection. For some events such as sunny-day dam failures or floods, radiation accidents, some chemical accidents, and some nuclear war scenarios, visual cues are essentially lacking. Substitution of visual cues in the warning process may help overcome this constraint, but the specific impacts of variation in the style and content of warnings on propensity to evacuate is largely unknown.

6.2.3 Hazard Characteristics Constrain Evacuation Effectiveness

The speed of onset of some hazard events is a major problem for effective evacuation within a subset of hazards. If a 90-second warning is available for an earthquake, a 10-minute warning for a dam failure, or a 20-minute warning for a nuclear war, what evacuation plans will maximize public protection? These short warning times present challenging scenarios for planning. This does not mean, however, that evacuations are not feasible--both earlier detection and better planning may enhance evacuation feasibility. However, the body of knowledge does not currently exist to optimize planning for fast-moving events or fast-developing concurrent hazards.

6.2.4 Planning Increases the Threat or Risk of Hazard

Critics have argued that emergency planning increases the likelihood of nuclear war and the probability of nuclear power plant accidents. There has been no research to prove or disprove the validity of this argument. Logical arguments can be formulated to support either opposite positions or a "no effect" conclusion. The motivation for preparing such arguments is largely ideological or political in nature, and further research is unlikely to change that.

A related issue that is more relevant and more important is whether evacuation plans increase the threat or consequences of a hazard if it occurs. Planning may allow increases in population in areas at risk or may justify not implementing other types of mitigation measures for protection. A further issue is that the evacuation plan may fail. Anecdotal evidence suggests that all three problems occur for different hazards. Research on this topic should be in broader programs of hazard management. However, such research would not greatly enhance evacuation planning but could improve hazard mitigation policies overall.

6.3 ISSUES CONCERNING WARNING CHARACTERISTICS

6.3.1 Uncertainty in Ability to Alert

6.3.1.1 Lack of warning systems

Critics argue that existing warning systems are inadequate to inform the public to evacuate. This lack of warning capability exists both at the local level and nationwide. The absence of warning systems can be attributed to three major factors. The first is a lack of a national policy in some areas and for some hazards to guide development of emergency programs. Second, existing policy may actually discourage the adoption of warning systems. Third, there may be a lack of resources for implementing the warning systems. The hazards for which warning systems do not exist are those recently defined as hazards that have not been the cause of any major catastrophes in the United States. These includes earthquakes, hazardous material accidents (both fixed-site and transportation), dam failures, and flash floods. Extending the adoption of warning systems is not limited by knowledge but by policy and resource availability.

6.3.1.2 Timing of warnings

The speed of onset of some hazards dictates that warnings be issued within very short time frames. For a number of hazards, including flash floods, local tsunamis, fixed site hazardous materials events, and transportation accidents involving hazardous materials, the effectiveness of current warning dissemination mechanisms and capabilities is questionable because of the lack of warning system hardware and appropriate planning. In many locations, the ability to evacuate depends on the

existing resources and the ability of emergency workers to provide warnings. In some cases, this will likely be inadequate depending on the impact of the event. Nuclear power plants have developed systems that can provide quick alerts, but the systems' ability to provide instructional information about protective actions remains questionable. Additional research is needed to improve planning for issuing short-time warnings to support both evacuation and other forms of protective action.

6.3.1.3 Warnings and information will be withheld

There is public concern that persons and organizations involved in the evacuation warning process may withhold information for a variety of reasons. Anecdotal evidence from case studies indicates that, on occasion, some warning or parts of a warning to support an evacuation are indeed withheld from the public. Often this is done by rationalizing that the public will panic, that the evacuation will be expensive, that it will be a false alarm, or for some other reason. For certain hazards, such as hazardous material accidents or nuclear power plant accidents, it has been alleged that it would be a conflict of interest to order an evacuation or inform the public. Research does not indicate how prevalent this problem is in reality. Furthermore, the conditions under which information is withheld have never been systematically identified or analyzed but doing so would unlikely improve evacuation planning.

6.3.1.4 Inadequate organizational communication

In some cases, inadequate organizational communications have led to poorly implemented evacuations. Research has indicated that communications play a major role in determining the operational effectiveness of organizations in emergencies. While poor communication can impede effective evacuation, it does not preclude successful evacuation. The conditions that lead to good vs poor organizational communication in emergencies are not well understood. Hypotheses based on organizational theory could be developed and tested to improve our understanding of failures.

6.3.1.5 Risks not revealed to warning organizations

The ability to evacuate depends on good communication between the hazard detectors and those who will disseminate the warning (i.e., the risks and the area potentially affected) in a timely fashion. There are certainly reasons to suspect that there is a problem for some hazards, including fixed site accidents and accidents involving the transportation of hazardous material. Although the problem has surfaced as an issue for nuclear power, the existing regulations, as written, address this broader concern.

6.3.1.6 Warnings will not be issued to transient populations

Transient populations do present difficulties in disseminating evacuation warnings. Anecdotal information suggests that there have been problems with warning vacationers of impending hurricanes and with warning campers in recreational areas to evacuate because of flash floods. Little systematic data exist on the receipt of warnings and the evacuation behavior of transient populations. Research on this topic could be valuable in developing evacuation plans in areas where large transient populations might be exposed to threats.

6.3.1.7 Siren systems cannot be heard

Considerable research has been done on receipt of warnings in general, and some research has specifically investigated the receipt of siren warnings. This research has indicated effective warning methods as well as the problems involved in issuing warnings. While the issue of the effectiveness of using sirens in warning systems has some validity, it is well established that warnings from sirens can be heard, and no further research is needed to demonstrate this fact.

6.3.2 Information Constrains Evacuation

6.3.2.1 People do not understand warning's special terms

The topics of warning clarity and evacuation behavior have been fairly well researched and the generalized relationship well demonstrated. Lack of clarity in a warning message constrains response (e.g., the lack of understanding of special terms that have a specific meaning for evacuations). Warning policies could be reviewed to determine the extent of this problem, but additional research is of low priority.

6.3.2.2 Probabilities are not understood or are misinterpreted

Some limited research has shown that, while it is true that people do not fully understand probabilistic information given in a warning message, it is also true that people do not pay much attention to probabilities that are included in warning information. Additionally, officials who issue evacuation orders have a better understanding of probabilistic information but do not use it in deciding to evacuate. These conclusions are mainly derived from experimental studies on hurricanes and should be validated by studies of experience in actual hurricanes. The current Parkfield earthquake prediction for California provides a good opportunity to study the use of probabilistic information in a field setting.

6.3.2.3 Multiple messages create confusion

Multiple sources of conflicting advice regarding evacuation can arise in extended or long lead-time situations. Considerable research suggests that this issue is a valid concern. Inconsistency in warning information creates confusion and leads to indecision. No further research is needed to confirm this. It should be addressed as a policy issue for such hazards as hurricane, earthquake, volcano, and other similar events for which there is a potential problem.

6.3.2.4 Warning content is inadequate

Inadequate message content does constrain evacuation. The problem exists, however, in defining what is adequate. At this point, research has outlined what is believed to be necessary, but that base of knowledge can be improved. Additional research on effectiveness of alternative message content is needed to fine tune warning message content. Implementing what is currently known in practice is the second issue of great importance. The state of knowledge about effective warning content is not reflected in practice in many evacuation situations.

6.3.2.5 Warning credibility

It is well known that credibility of information affects its use by potential evacuees. Research has shown that credibility is an important factor in evacuation decisions and has illustrated some of the ways it may constrain evacuation efforts. General knowledge would offer some ideas on how to deal with credibility problems and on how emergency warnings could be made credible. The precise ways in which credibility effects evacuation decisions have not been sufficiently researched to understand when credibility specifically interferes with evacuation behavior. This is not high-priority research.

6.3.2.6 Frequency of information

In extended warning periods, people want to receive information frequently. Typically, people want more information than is being disseminated. This runs counter to images of a public confused by an overload of information. In most warning situations, the public actively seeks out information in the process of confirming the warning. Furthermore, frequency of information receipt is positively related to evacuation behavior. On the basis of this knowledge, policy regarding frequency of warning should be reviewed for hurricane evacuation and for other hazards with potentially long lead times.

6.3.2.7 People do not understand sirens

Some research suggests that siren systems have failed to provide good evacuation warnings to the population. The effectiveness of siren systems, however, is not precisely understood, particularly in different social settings. Their chief function is to alert people to seek additional information. In actual emergency conditions that call for rapid evacuation, the reaction of people to sirens is largely unknown. Further behavioral research would provide a more solid base for making decisions on siren effectiveness and on how much education and training are needed to support an effective siren warning system.

6.4 ISSUES CONCERNING SOCIAL CHARACTERISTICS

6.4.1 Social Factors Color Risk Perceptions

6.4.1.1 Mitigation gives a false sense of security

There are many reasons why people who are advised to evacuate choose not to do so. One general reason is that people perceive themselves to be safe. It is likely that in some situations the presence of a mitigation structure, such as a dam or a seawall, influences the perception of personal risk. People may believe that the protective structure obviates the need to leave their homes, and they may fail to consider the possibility that the structure may fail. The strength of this belief and the extent to which it operates to constrain evacuation is not known. Additional research could be done on the topic as part of more comprehensive behavioral studies but special research is not warranted.

6.4.1.2 Experience

Experience with a prior evacuation is believed to influence human behavior in a subsequent threat situation. Research is fuzzy, however, about the nature of the effect. Five possibilities have been identified. First, people who narrowly escape or those who stay and actually experience the event are more likely to evacuate if another threat materializes. Second, people who evacuate and avoid the disaster are more likely to evacuate when threatened again. Third, people who stay and experience minor effects of the event are less likely to evacuate the next time. Fourth, people who leave unnecessarily are less likely to evacuate should the threat occur again. Fifth, people without any prior experience are more likely to evacuate. The strongest support exists for the third and fifth statements. Anecdotal evidence does not support the fourth statement. The first two statements are largely untested. Sorting out these relationships is important to improve planning in areas that may have recurring evacuations.

6.4.1.3 Depersonalization

Depersonalization occurs when people acknowledge the existence of a hazard but deny that it will affect them personally, "It cannot happen to me." People who depersonalize a threat are less likely to evacuate. Research suggests this rationale is likely a valid problem that should be addressed by warning system policy. Additional research is not necessary.

6.4.1.4 Fear of radiation

There is little evidence to suggest that fear of radiation will cause panic or massive population moves that could constrain effective evacuations. This statement is based on a limited number of observations. Should a very large amount of radiation actually be released, we can only hypothesize that human behavior would be similar to that experienced to date (e.g., TMI, where this did not occur). Additional research on human evacuation behavior during radiological accidents should be conducted following any future events.

6.4.1.5 Deny the hazard exists

Research suggests that people who deny the existence of a hazard are less likely to evacuate when the threat occurs. This denial may be the result of habitual exposure to the threat or of the rarity of the event, and it is a valid issue in evacuation planning. Research is less firm in suggesting the conditions that cause this to be a problem or the measures that can be taken to overcome such resistance.

6.4.1.6 Lack of preparedness

Mainly, the lack of preparedness has been an issue in emergency planning for nuclear war survival--in the context of lack of support for or opposition to defense policy planning. Research has shown that people who plan for an evacuation are more likely to evacuate. We can only speculate that opposition to planning would constrain an evacuation in a wartime setting. The best hypothesis is that lack of preparation of plans would constrain such efforts, but the extent to which the absence of plans would reduce evacuation is not estimable. Overall, understanding the relationship between levels of planning and response effectiveness would be valuable knowledge in determining necessary levels of preparedness.

6.4.1.7 False alarms

Contrary to popular belief, false alarms have not been a problem in getting people to evacuate when future threats occur. This conclusion is largely based on anecdotal evidence from recent hurricanes but is

also supported by experimental research. If people understand the uncertainty and basis of the false alarm, it is less likely to pose a problem when a subsequent event occurs. Further research on this topic could be conducted in a field setting if other false alarms do occur.

6.4.2 Factors Color the Ability to Receive Warnings

6.4.2.1 Culture and ethnicity

There is sufficient knowledge on the evacuation behavior of diverse ethnic groups to prevent it from being an issue. Research shows that members of societies with distinct cultural characteristics are less likely to evacuate for several reasons including language, isolation from authority, beliefs, and so forth. The problem needs to be addressed, however, as a policy issue. For example, in Los Angeles over one hundred different languages are spoken.

6.4.2.2 Disbelief in the ability to detect or predict

Some people do not trust the ability of scientists or other hazard monitors to accurately predict. This is a relatively minor issue. Information at the time of the evacuation will be more significant in shaping response behavior than pre-existing perceptions. No further research except as part of more comprehensive evacuation studies is needed.

6.4.2.3 Lack of understanding of hazardousness

This continues to be a problematic issue which constrains evacuation. For example, some people do not understand that fast-moving, high-velocity waters can float cars and buildings away, that volcanic ash creates breathing problems, or that storm surge is generally the most dangerous aspect of a hurricane. The problem is part of the larger issue of providing education and information that will enable people to more accurately perceive the risk. The topic of pre-event education and its effect on evacuation behavior requires additional research to understand how the problem can be reduced and how optimum education can be provided.

6.4.3 Factors Affecting the Ability to Evacuate

6.4.3.1 Economic resources

Research suggests that in some situations the lack of economic resources does constrain evacuation, that is, people with lower incomes are less likely to leave. In other cases, this relationship does not hold true. Additional research is unlikely to change these findings. Removing this constraint is a policy decision.

6.4.3.2 Special or institutional populations

This is a valid and important issue in evacuation planning. There are special populations and institutional populations that require specialized warnings and assistance to evacuate. The key issue is identifying the particular problems and needs of the different groups or institutions. Some research has been done on this topic, and current work is addressing some additional groups. Overall, however, the knowledge base to formulate evacuation plans for such groups is lacking and needs to be improved.

6.5 ISSUES CONCERNING ORGANIZATIONAL CHARACTERISTICS

6.5.1 Planning Elements are Inadequate

6.5.1.1 Coordination of planning is lacking

Research shows that the lack of coordination in the planning process among the organizations that will manage an evacuation can create problems that may lead to a poorly implemented evacuation. This problem has been observed in a number of different hazard events. Problems are particularly evident when events involve multiple jurisdictions and cross political boundaries. It is still unclear, however, why some organizations fail to effectively coordinate emergency responses, while others can not only overcome the problems in emergencies but also effect innovative and lasting improvements in their emergency response patterns. Additional research on organizational decision making would improve our understanding. The level of effort to be devoted to coordinating responses among various jurisdictions and different levels of government remains a policy issue.

6.5.1.2 Inadequate planning for shelters

Adequate research has been conducted on the provision of temporary shelters for evacuees. The problems in operating centers are largely understood and documented. Demand for shelters or expected use by evacuees is also known. However, whether or not this knowledge is being used by the responsible agencies for evacuation planning is an issue. The evidence tends to suggest that shelter planning for most evacuation situations is adequate.

Several special shelter issues require elaboration because they are uncertain. First is the concept of vertical evacuation in hurricanes. Ongoing research is addressing this option; however, the basis for demonstrating the logistics of moving people to the safe buildings may not exist. The safety of structures is also an issue but is beyond the scope of this report.

Second, evacuation to decontamination shelters in the event of a nuclear power plant accident or hazardous material emergency is an

issue on which little data exist. It is known that people go to a variety of destinations in an evacuation. The number of people who would go to a decontamination site would largely depend on information in the warning messages and the dissemination of the messages at the time of the event.

Third, the adequacy of shelters is an issue for large-scale evacuations such as for nuclear war. It is possible to show how much shelter is available although whether the shelters are properly located is uncertain.

6.5.1.3 Lack of plans

The development and adequacy of evacuations plans for generic and specific hazards are major issues. Neither the number nor quality of evacuation plans in this country is currently known. It is known from a review of planning and policy that the extent of planning is more problematic for some hazards (e.g., earthquakes, flash floods, hurricanes, dam failures, tornadoes, hazardous material accidents, and for nuclear war). Research is needed to measure and evaluate the adoption of evacuation planning in the United States.

6.5.1.4 Planning for secondary hazards

Anecdotal case studies suggest that evacuation plans for secondary hazards are inadequate. Notable situations include volcano-induced mudflows and floods, ashfall, sunny-day dam failures, flash floods during tornado episodes, and seismic-induced landslides. This inadequacy points out a need for research that can better support the development of plans for multiple or concurrent hazardous situations.

6.5.1.5 Definition of emergency planning zones (EPZ)

This has chiefly been an issue raised in nuclear power plant evacuation planning, although minor issues along this line have surfaced for other hazards. An EPZ is mainly developed on the basis of the physical impact area of a hazard, the resources at risk, and the feasibility of protective action. It is beyond the scope of this research to determine if the distance of ten miles for a nuclear power plant EPZ is correct. The research that has been reviewed suggests, in a different light, that the definition of an EPZ is not critical. In fact, some researchers suggest that defining an EPZ may obscure the important point that evacuation plans must be flexible enough to handle a range of scenarios that might extend beyond or affect only a small part of an official planning zone.

6.5.1.6 Plans for institutional facilities and special populations

The extent to which plans for special facilities have been developed is largely unknown. This information may exist for some types of facilities within trade associations or agency data. The technical basis for evacuation planning is largely missing for most facility types but, again, may exist within the industry. General emergency or fire plans may be adequate and useful in an evacuation.

6.5.1.7 Planning for reentry

Reentry has been noted as a problem in studies of some evacuations, including hurricane Diana and the Mississauga train derailment. Reentry criteria are rarely specified in detail in evacuation plans. Reentry problems are often exacerbated by poor organizational coordination, by lack of communication with technical experts, and by media reports.

Issues associated with reentry have been identified. The first concerns the decision as to who should be allowed into evacuated areas before the general population is allowed to return. The second concerns the management of people who attempt to converge into the risk area merely to observe. Both issues have implications for the assumption of liability as well as for the planning of resource use.

6.5.1.8 No support for planning

There are hazards and situations for which people oppose the development of evacuation plans. Actually, there are two types of opposition: ideological and fiscal. People and communities have opposed the development of evacuation plans for nuclear war and nuclear power plant accidents as a political statement. This will likely continue as a political strategy. People also oppose planning because they do not want to spend money for plans, or they view other needs as having more priority. This is part of the normal process of democratic decision-making. While support for and opposition to emergency planning is an interesting research question, it is not of great priority.

6.5.1.9 Planning for emergency resources to support evacuees

The main difficulty in researching this issue is establishing valid assumptions about the character of the evacuation (i.e., how many people would evacuate and for what length of time). Research demonstrates that it may be feasible to relocate resources such as food and water if sufficient supplies are available, if transportation is fully mobilized, and if people evacuate to planned areas. Research also shows that this may be difficult to achieve for certain host areas depending on the size of the incoming population. There is no solid empirical support for most of these assumptions.

6.5.1.10 Planning for medical and health care of evacuees

Evacuees typically will include many people who require special medical attention. Much of the discussion in the section on planning for special populations and institutional facilities applies to this issue. The chief difference is one of scale, and insufficient knowledge exists to know whether or not such planning for medical needs is feasible.

6.5.1.11 Planning for extended evacuations

An extended evacuation in which no attack occurs presents a difficult situation. Research suggests that, if such is the case, some people who evacuate will return. The numbers and timing of return trips cannot be estimated. Even without an officially ordered evacuation, it is likely that the government will have to provide substantial advice during a crisis situation. This issue has both policy and research implications. Clearly a policy is needed to guide this matter. Research is needed to provide the basis for the policy.

6.5.1.12 Planning uses the wrong assumptions

Research has shown that planning for evacuations should cover a range of scenarios, although considering every single scenario is not possible. Plans should be flexible enough to handle a range of scenarios or new contingencies. There is no reason that this philosophy should not apply to war threats as well.

6.5.2 Training of Evacuation Personnel is Inadequate

Better training will likely improve evacuation planning and execution. Training can be accomplished by organizing existing knowledge into training courses to better prepare all emergency personnel. It is not a research issue because knowledge exists to do this. It is mainly a problem of implementation and resource allocation.

6.5.3 The Technical Basis for Evacuation Planning is Inadequate

6.5.3.1 Evacuation time estimates are inaccurate

A variety of models exist to estimate the time required to evacuate specific geographical areas. The models are definitely useful in evacuation planning and are likely to provide better estimates than seat-of-the-pants guesses. How accurately they predict actual evacuation times is a valid issue. Assumptions in the models require closer scrutiny. There is a need to conduct empirical research to fine tune and validate the models to provide more accurate and certain estimates of evacuation times.

6.5.3.2 Plans will lead to unnecessary evacuation

This issue of unnecessary evacuation has been raised in connection with hurricanes. Officials will probably evacuate areas unnecessarily because the exact impact areas are uncertain. This is a policy decision. Improvements in forecasting may eventually narrow the 24-hour window currently used.

6.5.3.3 Organizations for developing plans are lacking

The issue of organizational planning has been raised regarding hazardous-material accidents at fixed sites and during transportation. While it is not true for all locations in the United States, the issue is valid for the nation overall. While recent legislation established the requirements for state and local plans, it is unclear how these regulations will be implemented. This implementation process should be tracked.

6.5.3.4 Organizations with responsibilities downplay the hazard

Anecdotal evidence does suggest that agencies responsible for dams and hazardous materials have, on occasion, downplayed the need for emergency planning. This has occurred due to politics, a desire not to deal with the issue, and a lack of mandate to resolve the problem. Again this is a policy issue. Resolution of this issue is not a research activity.

6.5.3.5 Knowledge not transferable

Some caution does need to be exercised in transferring knowledge about evacuation derived from one event to planning for other hazards. The same holds true for knowledge derived from one class of events to another. This does not mean it cannot be done. In the absence of hazard-specific knowledge, it may be possible to apply concepts but not specific instances. This, however, is certainly an issue which requires more research attention.

6.5.3.6 Dissemination of technical knowledge is poor

The quality of technical information incorporated into evacuation planning likely varies between different communities and states. The extent of this variation is known in general terms; however, it likely differs among hazard types. For example, there is much less variance in the technical knowledge in nuclear power plant evacuation plans than in the evacuation plans for hurricanes or flash floods.

6.5.3.7 Populations at risk are unknown

Evidence suggests that knowledge of populations is valuable in developing or implementing an evacuation plan. The necessary amount of detailed data to incorporate into evacuation plans is unclear. Also, a satisfactory method for periodically updating plans to include changes in population parameters is not presently known.

6.6 ISSUES CONCERNING RESPONSE CHARACTERISTICS

6.6.1 Physical Factors Constrain Evacuation

6.6.1.1 Population too dense to evacuate

Anecdotal information exists from case studies regarding the ability to evacuate some densely populated areas but does not include evacuating extremely large populations. Such evidence comes from studies of wartime evacuations, the large-scale Mississauga evacuation, or Gulf and East Coast hurricanes. Additional knowledge has come from modeling studies, but the results have been questioned because of the assumptions used. It is unclear, therefore, how long it would take to evacuate large and densely populated cities or regions, and further investigation is needed.

6.6.1.2 Population in areas with seasonal peaks

The ability to evacuate tourist populations from areas subject to nuclear power plant accidents or hurricanes is a valid issue. Questions regarding knowledge of evacuation routes, use of shelters, behavior of evacuees, timing of evacuation, or the potential problems of traffic congestion should be addressed in planning. There is not a great deal of research to support analysis of these issues. Anecdotal experience provides some information, but even good case studies are lacking. Behavioral research has not focused on studying tourists as a population, so behavioral knowledge is poor. Traffic modeling studies provide data on the length of time required to evacuate some areas and are useful within the bounds of uncertainty governing those studies. Application of general knowledge suggests that evacuation of seasonal-peak populations is probably feasible, but additional knowledge would improve planning and implementation of plans.

6.6.1.3 Boats will interfere with island evacuation

This interference caused by boats that require the raising of drawbridges is an issue of logistics in certain hurricane settings. The optimum strategy for control of drawbridges should be a problem that most local transportation planners can resolve.

6.6.1.4 Traffic accidents will constrain evacuation

There is no research to date that suggests that excessive traffic accidents are likely in an evacuation. Limited research and observation suggest that accident rates are lower during evacuations, probably because of increased driver vigilance and lower vehicle speeds. Ongoing research may provide a more definitive answer to this issue.

6.6.2 Public Behavior

6.6.2.1 People will hold parties instead

Anecdotal evidence and survey research show that people do not evacuate for a variety of reasons. One media-driven image is that of hurricane parties or similar activities during other events. Such parties do happen, but the number of people involved, while unknown, is likely small. The problem of non-evacuation does raise some other more serious issues. Such behavior frequently makes it necessary for emergency workers to rescue trapped people, often exposing themselves to risks and occasionally losing their life during rescue attempt. It is a policy decision whether to rescue people who do not evacuate. The problem concerns the potential question regarding liability of public officials for members of the public at large.

6.6.2.2 Evacuation shadow

The evacuation shadow exists by definition either spatially or demographically. A shadow is judged retrospectively and often with an arbitrary indicator of who or what area was ordered to evacuate. As such the definition ignores the social processes in disaster. Research has shown that perceived threat or risk at the time of the disaster is a central reason for persons evacuating. Research also shows that evacuation declines as perception of threat decreases and distance from the threat increases. Even if one accepts the validity of the shadow concept, it can be concluded that it has been poorly studied. Behavioral studies have either failed to include a variety of risk areas in investigations or have inadequately sampled the alleged areas of shadows. Thus what we know about spatial variation in evacuation rates and what causes the variation is rather limited; however, research on this topic will produce little added knowledge. Behavioral intent studies do little to remedy this situation.

6.6.2.3 Panic

The conditions under which panic occurs are well understood. Panic rarely occurs in evacuations, and the conditions for panic are not likely to occur, but their occurrence is not impossible. One problem is that officials and the media often mislabel certain behavior as

panic; thus, the myth is perpetuated. No further research on panic is needed unless a situation does occur in which panic takes place.

6.6.2.4 Convergence

Little research has been done on convergence, and there has been virtually no research on how convergence interferes with evacuation efforts. Studies suggest that convergence occurs in many disasters during both the pre- and post-impact periods. It poses significant problems for officials who are in charge of controlling access to evacuated areas or directing traffic. The conditions that promote convergence in certain events but not others are largely unknown The media is suspected of playing a role in stimulating convergence. Further research could provide more answers regarding mitigation of the problem.

6.6.2.5 Spontaneous evacuation

As for shadow, this concept of spontaneous evacuation exists by definition. The issuance of an official order is an arbitrary yardstick by which behavior is judged. Other types of information, including messages that an evacuation is likely or that an unofficial evacuation is recommended, will cause some people to evacuate--the reasons for such spontaneous action are more speculative. Anecdotal information suggests that the reason may be to avoid having to evacuate when officially ordered or simply to be sufficiently cautious.

6.6.2.6 Aberrant behavior

The research evidence of aberrant behavior among evacuees is practically non-existent. Hostile behavior, particularly toward emergency workers, does not occur during evacuations. Looting occurs but is extremely rare. Crime rates are believed to decrease during evacuations, and the demand for police services for non-evacuation or emergency functions decreases. Aberrant behavior is typically a myth that tends to be perpetuated by the media which covers isolated instances, misinterprets behavior, or falsely associates an unrelated incident with an emergency.

6.6.2.7 People will not use specially designated routes during evacuations

No one has specifically done a detailed investigation of the actual routes people use when evacuating. Thus it remains a major issue for traffic time estimation models. The most reasonable assumption is that people will use routes they normally use, except when the routes are blocked or when they are specifically directed by law enforcement personnel to use a different route.

6.6.2.8 Stress will occur due to evacuation

There has been no empirical research on the stress specifically experienced during evacuation as opposed to the entire emergency or disaster experience. A number of studies suggest that stress is elevated by disasters, and the levels vary among individuals and among disasters. It is unknown at what point during the warning-response-recovery sequence stress levels are elevated. There is no direct evidence that stress is dysfunctional during an evacuation. In fact, the low rate of traffic accidents provides some evidence to the contrary. Another unknown is the issue of whether stress may cause people not to evacuate. These topics are related to the broader set of issues dealing with disaster-related mental health disorders and should be placed in that perspective. Further research is needed and presents many methodological challenges.

6.6.2.9 People will not obey officials

There is considerable amount of anecdotal evidence which suggests that a very small percentage of the public will disobey official orders. Part of the problem in addressing this issue is the definition of an official order which range from recommendations to evacuate to active attempts to get people to leave designated areas. In other words, this problem is related to the strength and perceived credibility of the official orders. In high-risk situations where door-to-door orders to evacuate are issued, 98 to 99% of the population under threat will likely evacuate. In less forceful situations, the number evacuating can be substantially lower, but it may be improper in those situations to define that behavior as being disobedient.

6.6.2.10 People will not evacuate for long periods of time

Research shows that in prolonged evacuation there is a tendency for people to return or want to return as soon as possible. In some evacuations, people leave without knowing how long the evacuation will last. People do not take sufficient clothes, medicine, or other essential household items, pets that require care are left, businesses need attention, and so forth.

6.6.2.11 People do not know how to evacuate

There are some circumstances in which people do the wrong thing when evacuating because of a lack of knowledge or information. Research on this topic is mostly anecdotal. Research on the behavior of disaster victims who die in the course of evacuating is scant but suggests that some people take the wrong route because of inadequate information contained in poor warning messages.

6.6.2.12 People will shelter instead

The mix of people who continue with their normal activities, stay home, shelter, or evacuate in a crisis situation is inestimable. Behavioral intent surveys cannot be used to estimate what people will do in a threatening situation. The portion of the public that stays home, seeks shelter, or evacuates will depend on the nature of the emergency and the available information. The extent to which the situation and information resemble previously experienced events improves the public's basis for estimation. For example, in a high-threat situation, a long lead time and good warning information could result in higher compliance with recommended actions, particularly if the recommendation includes understandable, rational evacuation procedures.

6.6.2.13 People will not go to designated host areas

In most evacuations, people are usually not instructed to go to specifically designated areas. (This is different from going to assigned shelters.) When instructions are absent, research has shown that people usually choose to go to friends, relatives, or a motel when evacuating. No research has been done to infer how many people would go to a designated host area if instructed to do so by a credible source. In part, the number doing so would be determined by the information provided and the degree to which movements were controlled.

6.6.2.14 Total social chaos

There is no evidence to suggest that the social order would break down because of evacuation during a war crisis. Historical evidence runs totally to the contrary. The argument that nuclear war is unique and horrible does raise a possibility that more chaos would occur, but it is unlikely that a total breakdown of civilization would occur in the pre-impact evacuation period.

6.6.3 Emergency Worker Behavior

6.6.3.1 Role abandonment

Role abandonment has been a controversial issue for some hazards. Research suggests that total role abandonment has not been prevalent in disasters and certainly has not been dysfunctional in organizational behavior. Some people have hypothesized that role abandonment would be greater and likely problematic in a nuclear power plant accident or during a nuclear war threat. This remains somewhat speculative. Research suggests that in the former case there may be an increased potential for conflict and role strain, but emergency functions would not be threatened. In the latter case, the issue is highly uncertain. Additional research on role conflict would be confirmatory but is not of high priority.

6.6.3.2 Denial of evacuees

Host-areas' unacceptance of evacuees is an issue specific to nuclear war. It is largely speculative, and whether or not it would occur cannot be predicted. The most prudent hypothesis is that most host areas would receive evacuees, but denial could occur under certain conditions and in certain locations. Research on behavioral intentions is unlikely to help solve the ambiguity.

6.6.3.3 There will be no outside help to implement plans

Most evacuation planning assumes initial reliance on community resources with outside help over time if necessary. The resolution of this issue varies with the scenario projected. In some scenarios (e.g., the threat of a single weapon strike on a large city) it may be reasonable to assume that outside help would be available. On the other hand, an ordered evacuation of all urban areas could preclude the assumption that outside assistance would be available from within the continental United States.

6.6.3.4 Erosion of leadership

It is possible that strong leaders would not emerge in a war crisis. Based on research and experience to date, however, this is not the most likely hypothesis. Instead, it is more likely that a crisis would produce strong leadership that would extend throughout the evacuation. This is not to say conflict would not occur, particularly at local levels.

6.6.4 Evacuation is not Perceived as a Public Good

6.6.4.1 Evacuation puts people at greater risk

The act of evacuation can place people at greater risks in certain circumstances. As this report has stressed, evacuation is not, nor is it ever likely to be, a way of providing 100% protection against a hazard. Planning can minimize the extent or possibility of evacuation placing people at greater risk but only within the bounds imposed by our understanding and the predictability of hazardous systems. At present, the possibility of evacuating to higher risk areas is a constraint to the evacuation decision-making process, but it can be resolved through new research on organizational decision making.

6.6.4.2 People have right to stay

People's right to stay behind rather than to evacuate is a moral or philosophical issue that has no clear solution. On one hand, our society adheres to free choice when that choice does not damage other people or

property. On the other hand, people who do not evacuate can cause emergency workers to take greater risks (e.g., search and rescue of non-evacuees). The resolution of this dilemma is a policy question with no easy solution.

6.6.4.3 Evacuation planning creates liabilities

Evacuation does pose problems of liability. The major problem is that concern about this liability may impede effective decision making. The extent to which liability imposes other problems is basically a matter for the courts to resolve. Indications are that litigation over evacuations, along the lines raised in Chapter 2, will continue in the future and perhaps become more common than in the past.

6.7 SUMMARY

In this chapter we have considered the knowledge presented in the preceding three chapters in relation to the evacuation issues identified in Chapter 2. Table 6.2 attempts to summarize the findings on each issue with respect to four areas of concern:

1. Valid issue--based on existing knowledge, does the issue appear to be valid;

2. Knowledge adequate--is the research base adequate to understand the issue and develop means for resolving the issue;

3. Need research--would added research significantly contribute to improving the basis of evacuation policy;

4. Policy review--given existing or potential future knowledge, should policies and programs be reviewed in order to improve the implementation of evacuation plans.

Based on a review of this table, the following generalized findings can be offered. First, many of the issues identified indeed pose valid points to consider in developing a state-of-the-art evacuation plan. Other issues identified can be dismissed by planners without grave concern. Second, many issues are not fully understood or solutions for overcoming the issues cannot be confidently defined given the existing state of knowledge. Some, however, can be confidently addressed using existing knowledge. Application of existing knowledge in any event can improve evacuation planning for many hazardous situations. Third, a careful review of existing policy and procedures will aid in resolving many of the issues without conducting further research.

Table 6.2. Summary of knowledge on evacuation issues

	Valid issue	Knowledge adequate	Need research	Policy review
Physical Hazard Characteristics				
Uncertainty in ability to specify hazard parameters				
- Location, timing, magnitude, effects	Yes	No	Yes	No
- Secondary hazards	Yes	No	Yes	No
Uncertainty in ability to detect hazards				
- Scientific ability	Yes	No	Yes	No
- Lack of physical cues	No	Yes	No	No
Hazard characteristics constrain evacuation effectiveness				
- speed of onset	Yes	No	Yes	No
Planning increases the risk of hazard	No	No	No	No
Warning Characteristics				
Uncertainty in ability to alert				
- Lack of warning systems	Yes	Yes	No	Yes
- Timing of warnings	Yes	No	Yes	No
- Information withholding	No	No	No	No
- Inadequate communication	Yes	No	Yes	Yes
- Risk not revealed	Yes	Yes	No	No
- Warnings not issued to certain groups	Yes	No	Yes	Yes
- Sirens not heard	No	Yes	No	No
Information constrains evacuation				
- Special terminology	Yes	Yes	No	Yes
- Probabilistic information	Yes	No	Yes	No
- Multiple messages	Yes	Yes	No	Yes
- Inadequate content	Yes	No	Yes	Yes
- Credibility	Yes	No	Yes	No
- Frequency	Yes	Yes	No	Yes
- Siren use	Yes	Yes	No	No

Table 6.2. (continued)

	Valid issue	Knowledge adequate	Need research	Policy review
Social Issues				
Social factors color risk perceptions				
- Mitigation measures	Yes	No	No	No
- Prior experience	Yes	No	Yes	No
- Depersonalization of threat	Yes	Yes	No	Yes
- Fear of radiation	No	No	No	No
- Denial of hazard	Yes	No	Yes	No
- Denial of need for preparedness	Yes	No	Yes	Yes
- False alarms	No	No	Yes	Yes
Factors color the ability to receive warnings				
- Culture and ethnicity	Yes	Yes	No	Yes
- Disbelieve ability to detect or predict	Yes	No	No	No
- Lack understanding of risk	Yes	No	Yes	No
Factors affecting the ability to evacuate				
- Economic resources	Yes	No	No	Yes
- Special or institutional populations	Yes	No	Yes	Yes
Organizational Issues				
Planning elements are inadequate				
- Coordination of planning is lacking	Yes	No	Yes	Yes
- Inadequate planning for shelters	No	Yes	No	No
- Lack of plans	Yes	No	Yes	Yes
- Planning for secondary hazards	Yes	No	Yes	Yes
- Definition of epz	No	Yes	No	Yes
- Plans for institutional facilities and special populations	Yes	No	Yes	Yes
- Planning for reentry	Yes	No	Yes	Yes
- No support for planning	No	No	No	Yes
- Planning for emergency resources	Yes	Yes	No	No
- Planning for medical and health care	Yes	Yes	No	No
- Planning for extended evacuations	Yes	No	Yes	Yes
- Planning uses the wrong assumptions	Yes	Yes	No	Yes
Training of personnel is inadequate	Yes	Yes	No	Yes

Table 6.2. (continued)

	Valid issue	Knowledge adequate	Need research	Policy review
The technical basis for planning is inadequate				
- Time estimates are inaccurate	Yes	No	Yes	No
- Plans will lead to unnecessary evacuation	No	Yes	No	Yes
- Organizations for developing plans are lacking	Yes	Yes	No	Yes
- Organizations downplay the hazard	Yes	Yes	No	Yes
- Knowledge not transferrable	Yes	No	Yes	No
- Dissemination of knowledge is poor	Yes	Yes	No	Yes
- Population at risk unknown	Yes	Yes	No	Yes
Response Issues				
Physical factors constrain evacuation				
- Population is too dense to evacuate	Yes	No	Yes	No
- Population in areas with seasonal peaks	Yes	No	Yes	No
- Boats interfere with island evacuation	No	Yes	No	Yes
- Traffic accidents constrain evacuation	No	Yes	No	No
Public behavior				
- People will hold parties instead	No	Yes	No	Yes
- Evacuation shadow	No	Yes	No	No
- Panic	No	Yes	No	No
- Convergence	Yes	No	Yes	Yes
- Spontaneous evacuation	No	Yes	No	No
- Aberrant behavior	No	Yes	No	No
- People wont use special routes	No	Yes	Yes	Yes
- Stress will occur due to evacuation	Yes	No	Yes	No
- People won't obey officials	No	Yes	No	No
- People won't evacuate for long periods	Yes	No	No	Yes
- People don't know how to evacuate	Yes	No	No	Yes
- People will shelter instead	Yes	Yes	No	Yes
- People will not go to designated areas	Yes	No	Yes	Yes
- Total social chaos	No	Yes	No	No

Table 6.2. (continued)

	Valid issue	Knowledge adequate	Need research	Policy review
Emergency worker behavior				
- Role abandonment	Yes	Yes	Yes	No
- Denial of evacuees	No	Yes	No	No
- Erosion of leadership	No	Yes	No	No
- No outside support	No	Yes	No	Yes
Evacuation not perceived as a public good				
- Evacuation puts people at greater risk	No	No	Yes	Yes
- People have right to stay	Yes	Yes	No	Yes
- Evacuations create liabilities	Yes	Yes	No	Yes

7. RESEARCH NEEDS

We do not recommend initiation of a single research project for each of the issues judged to need more research--to do so would be redundant and certainly not cost-effective. Instead, we have tried to define a set of studies, each addressing multiple issues. These studies are far from exclusive and, in fact, would benefit from some coordination between related projects. Because they address multiple issues, it is difficult to assign priorities; however, the conclusions address the relative importance of this research agenda. In total, we identify ten research efforts to help resolve problematic evacuation issues.

7.1 PLANNING FOR LARGE-SCALE EVACUATIONS

Planning guidance for evacuating large urban areas is limited by scant relevant past experience and the absence of research conducted from an evacuation planning perspective. Largely experience with large-scale evacuations has been limited to population movement in response to warnings of hurricanes and tropical cyclones. Creative and carefully constructed research is needed to enhance evacuation planning efforts for large populations. Past evacuation studies and experience must be utilized in developing guidance, but care must be taken in applying knowledge gained from experience with successful small-scale evacuations. The initial research agenda for this planning problem should emphasize an inductive approach rather than the deductive approach more commonly applied to developing planning guidance.

This research should first identify the widely-accepted concepts in the evacuation literature and, then, evaluate them with respect to their efficacy for large populations. In this review, the existing transportation planning guide for evacuating large cities and studies of larger pre-hurricane evacuations would be the focus of attention. Having established "confidence levels" for this information base, relevant planning concepts (for which there is little or no supportive research) must be subjected to a grounded-model-building exercise. This exercise should focus on the full utilization of seasoned expertise in two or three large urbanized areas. A concerted effort to build on existing emergency planning should be made, so it is likely that existing projects, such as the SCEPP project in southern California, and the Dade County planning effort, should be used to further the model-building effort.

A major method that could be used to build the model could be similar to a series of table-top emergency exercises. The themes should be focused to identify and solve the problems unique to large-population evacuation. Questions of public information needs, uses of organized volunteers, and unique logistical needs should be examined and remodelled to point to solutions and important unanswered questions.

A planning guide for large-scale evacuations will be the major product from the effort. But a secondary product is likely to be a research plan by which to identify further solutions and subsequent guidelines.

7.2 SPECIAL EVACUATION PLANNING NEEDS FOR FAST-MOVING EVENTS

Research should provide answers to several questions to increase the knowledge base for planning for evacuations because of fast-moving events. These questions fall into the categories of public response to emergency information and warnings and the organizational processes tying disaster detection to public evacuation advisements and warnings.

Relatively little is known about special planning needs associated with special pre-emergency public education regarding the need for a quick response when fast-moving events leave short times available for taking protective actions such as evacuation. The State of Hawaii, for example, has begun efforts to educate residents of Hilo. These people are being instructed to evacuate to high ground within five minutes after they feel an earthquake to avoid the threat of earthquake-generated tsunamis. California has recently become concerned about the possibility of having only a 90-second warning for an 8.3-Richter-magnitude earthquake in the southern part of the state. Additionally, hazardous material and chemical accidents pose increasing threats for initiating fast-moving events. The limited research available on the type, character, and effectiveness of pre-emergency public education for future fast-moving hazardous events is far from conclusive; yet research evidence and historical cases definitely indicate that the knowledge people bring to an emergency does effect their response. Cross hazard research is needed to determine useful topics to address in pre-emergency education aimed at fast-moving events, and to decide how to assemble and present that information to the public.

Fast-moving events pose another public response question. We know relatively little about the unique needs for actual emergency public warnings and information for fast-moving events. For example, it has long been known that most people will seek confirmation of warnings before deciding to evacuate. Because some emergencies are so fast moving, this confirmation process can lead to increased losses. Research is also needed which focuses on the social psychological aspects of emergency public information for fast-moving events. Hopefully, this research would produce findings that would enable endangered publics to make quicker evacuation decisions in response to fast-moving events.

Research on pre-emergency public education and on special emergency warning and information needs should be cross-hazard and should include natural phenomena, such as flash floods, as well as technological events, such as chemical spills resulting from train derailments. Additionally, this research should seek cross-hazard similarities (generic principles of emergency planning for fast-moving events), as well as unique hazard-specific findings. In the latter cases, particular attention should be

paid to how pre-emergency education and disaster warnings and information could help people choose alternative protective actions in lieu of evacuation where appropriate. For example, some chemical emergencies would not cost lives if it were known that people could simply cover their nose and mouth with a wet rag and stay indoors.

Fast-moving events, and effective public response to them, require that the hazard be detected quickly and that the public be informed rapidly. Three constraints may inhibit this process. Research is needed on how to overcome these constraints and streamline the processes that link hazard detection to public warnings.

The first of these constraints deals with the "hardware" aspects of a public alert. Research should address alternative schemes for alerting an endangered public: sirens, telephone systems, and the like.

The second constraint involves the processing of hazard information by people and organizations prior to issuing public warnings and information. Retrospective studies of recent historical events and research on events as they occur would help reduce the time needed to process risk information for fast-moving events before it is made public.

Finally, technical research is needed for some hazards to determine the actual risks of public exposure. This information must exist before planning can proceed.

7.3 EVACUATION PLANNING FOR CONCURRENT HAZARDOUS EVENTS

A three-pronged research effort is in order to address existing gaps in knowledge to provide a more informed basis for evacuation planning for concurrent hazardous events. These efforts follow.

First, physical science cross-hazard studies could identify the hazards' probabilities of occurring concurrently (e.g., fire and earthquake), considering both linked hazards (one causes another) and independent hazards (both occurring at the same time). This ranking would provide an informed basis for deciding which concurrent events should be planned for and which would be best ignored. This effort need be neither elaborate, time-consuming, nor expensive. A systematic assessment performed by an integrated team of experts would seem to be appropriate.

Second, it would be appropriate for emergency planning and behavioral response experts to jointly produce a systematic catalogue of planning needs for those concurrent hazards previously judged to be worthy of further planning. This catalogue of planning needs should detail generic issues, if any, as well as unique issues peculiar to particular and unique sets of concurrent hazards.

Finally, based on the prior planning assessment, prototype plans should be developed in some localities that can be transferred to others. This action-"research" component has already been shown to be effective

with the increased adoption of new planning issues with earthquake and earthquake prediction planning.

This three-step research process (physical science--emergency planning and social science--plan development) is sequential, it is easily based on existing knowledge which is neither well assembled nor integrated for the purpose of concurrent hazards planning, and it promises payoff.

7.4 HUMAN BEHAVIOR IN EVACUATIONS

The research needed would certainly take advantage of the knowledge already accumulated by individual warning systems research projects and would go several methodological, theoretical, and practical steps further. In order to address the problems stated, an integrated warning systems research effort should accomplish the following:

1. begin with the state-of-the-art factors that comprise warning system structure and direct human response;

2. evaluate these same factors across a wide range of geological, technological, and climatological emergencies to provide a sound basis for cross-hazard comparability;

3. provide for cross-hazard emergency comparisons in order to determine common themes--applicable in all warning systems--and hazard-specific factors; and

4. allow research to be performed almost immediately after an emergency before warning response data become too old.

The purposes of cross-hazard comparisons in this research should be

1. to determine common warning system elements for all hazards, for example, hardware and technologies, emergency organization, warning messages;

2. to address what common warning system elements can be used to reduce duplication of warning systems in the United States and integrate cross-hazard warning systems;

3. to suggest the common warning-system elements that would likely survive in emergencies not yet experienced, and draft a basis for warning system preparedness for those emergencies; and

4. to reveal hazard-specific elements of warning systems needed for use in preparedness for the full-range of potential hazards.

Finally, based on the findings of the comparison of emergency cross-hazards warning events studies, an assessment and cost-benefit analysis of existing warning systems in the nation should suggest alternative

fruitful paths for cross-hazard integration of warning systems design and technology.

7.5 ACCURACY OF EVACUATION TIME ESTIMATES

An integrated model for evacuation time estimates, based on clear assumptions and validated on the basis of actual data, is needed. Such a model could be tailored to different hazards, localities, and circumstances. Research to generate such a model would best be interdisciplinary and should involve traffic modelers, social scientists, and others. It should also be cross-hazards in character, and should address the range of problems that could affect evacuation time estimates (e.g., seasonal tourist populations, snow, other concurrent events, and so on). Three steps for this research are in order.

First, a thorough assessment should identify all models in use, the assumptions on which they are based, and the aspects of all hazards and circumstances that could affect evacuation time estimates. Second, empirical research should test the validity of all articulated and inarticulated model assumptions, using data sets from historical evacuations as well as gathered original data. For example, traffic data could be collected in actual evacuations as they occur. These data could then be compared to modelling estimates of the same evacuation. Finally, the results of the preliminary assessment could be combined with the empirical research on model assumptions to create a validated model/planning guide that would be adaptable across hazards and circumstances.

7.6 RE-ENTRY AFTER EVACUATION

The problems associated with re-entry after evacuation are not well known and have received little research attention. It is difficult, therefore, to say with confidence how they might be managed or how they might best be addressed as part of evacuation planning. We do know, however, that re-entry can be riddled with problems; recently, cases have occurred where evacuees have returned home before impact, for example.

Research on re-entry could be relatively straight-forward and could have high potential payoff. Two approaches are in order. First, research studies already performed should be systematically reviewed and data reanalyzed for anecdotes and evidence already in the hands of the research community. Most research performed to date on evacuation has focused on movement out of the area at risk. Researchers may have overlooked re-entry anecdotes since re-entry was likely not a research focus. Second, retrospective studies of recent cross-hazard evacuation events should be done. If selected carefully, evacuation managers and organizational respondents could be interviewed about re-entry problems in a dozen or so recent evacuations. Additionally, several surveys of recent evacuees should be performed to obtain better data on their behavior and to ascertain the problems they experienced.

7.7 PLANNING NEEDS FOR SPECIAL POPULATIONS

Evidence from past disasters has already indicated that evacuating institutionalized populations is a special planning problem. Research to improve planning for this problem area has begun and has led to the identification of other sub-populations needing specific planning attention, for example, tourists or non-institutionalized disabled persons.

To date, data from the various past and ongoing studies on this topic have not been reviewed and synthesized or published in such a way as to give visibility to the research on broader planning applications. Consequently, beneficial findings have been under-utilized for cross-population and cross-hazard planning. The next step on planning needs for special populations is to systematically review existing information to identify common findings and compare them in the context of available literature. This step could be readily accomplished by contacting the relevant researchers and agencies and soliciting their cooperation in providing insights, data, and written materials for systematic examination.

Examination of past experience and studies would provide three products. First, a synthesis of current knowledge would be reported. Second, those common findings supported by the existing literature, could be identified, translated, and suitably formatted into planning guidelines for immediate use by evacuation planners nationwide. The third product would be a detailed and prioritized research agenda. The agenda could derive from data gaps and topical exclusion of important features of the evacuation planning models currently known and accepted in the available literature.

7.8 LIABILITY FOR EVACUATION DECISIONS

Concerns and perceptions of liability for evacuation decision making, regardless of whether or not those concerns are founded, are frequently articulated by emergency managers. It has not, as yet, been documented if such concerns act to constrain actual evacuation decision making. If liability perceptions do constrain good evacuation decisions, research should also address how best to remove those constraints. Two studies are in order to address this issue, the first is behavioral in character, while the second is legal.

Evacuation decision makers who have participated in a broad range of natural and technological evacuation events should be interviewed concerning recent evacuation events. The focus would be on evacuation decision making, and the study would address, for example, the decisions that were made, when, and why. However, the decision makers should also be asked about factors that probably influenced their decisions, including liability. If this study included carefully worded questions, liability perceptions could be assessed without bias. The product from this study should be an estimate of the extent to which perceived liabilities affect

actual evacuation decision making, and if so, how and under what circumstances.

A legal study of actual liabilities over a range of evacuation decision making scenarios is also warranted. Such an effort should seek to determine, within practical limits and over a range of circumstances, the degree to which there are and are not grounds for liability associated with evacuation decision making.

The aim of both studies should be directed toward defining ways to remove liability or liability perceptions that could interfere with making good evacuation decisions.

7.9 UNCERTAINTIES IN EVACUATION DECISION MAKING

Uncertainties regarding decisions that lead to public evacuation advisements do and will continue to, affect all decision making in the organizations that are involved. Two research efforts are needed to help minimize the effects of these uncertainties. The first effort should identify these uncertainties and determine how they operate to detract from sound decision making. The second effort should center on evacuation decision-making aids in an attempt to remove the negative effects of uncertainties and to assist in making decisions.

It would be appropriate to proceed with several case studies of natural and technological events that focus squarely on inter- and intraorganizational decision making that could lead to evacuation. These studies should seek to systematically document the uncertainties that affect decision making at each point--from the detection of a hazard through the actual evacuation decisions. Additionally, the research should address the cause of any uncertainties that arose and what, if anything, could have helped reduce the negative effects of such uncertainties. The soundness of this research would depend on investigations beginning as soon as possible after, if not during, an evacuation.

Additionally, the role of decision making aids in evacuations should be investigated. Several studies appear promising. First, laboratory studies should research, in a comparative way, how various available decision-making models and aids might lead to different or similar evacuation decisions under different scenarios. The results of this research should enable the fine-tuning of good models and aids, as well as the abandonment of the less useful ones.

Second, the adoption of the models and aids should be investigated across localities engaged in evacuation decision making. An adoption-diffusion/transfer study could do much to enhance the use of good models and aids. Such a study would be particularly useful, for example, in hurricane decision making, since recent developments have led to the availability of new and good models.

Finally, research should be performed to identify the kind of information, aids, and models that could best assist decision-makers. This research should be from the point of view of the decision-maker or "user" (e.g., if decision-makers who have recent evacuation experience feel that "real-time" traffic data would be useful, how would a system best be designed for their use). Decision-makers who had recent evacuation experience in a variety of hazards would be surveyed.

7.10 ADOPTION OF INTEGRATED EMERGENCY MANAGEMENT SYSTEMS

That certain concepts are common to successful emergency planning for evacuations has been recognized and widely accepted. This commonality has been codified by the federal government through FEMA's efforts to encourage state and local officials to adopt an integrated cross-hazard approach to emergency planning and evacuation. This planning approach facilitates systematic information transfer of more detailed planning aids to state and local emergency officials.

To date, this integrated planning approach has been unevenly adopted at the state and local levels. However, that uneven adoption and, more importantly, the reasons behind it are not analytically documented. To enhance upgraded emergency and evacuation planning and to reduce disaster impacts across the nation, a study of this uneven application and the reasons for it is now needed. Findings from such research will, in turn, be used by emergency planning officials to broaden and upgrade utilization of the integrated planning approach and supplemental guidance.

The first step in the study should identify state emergency planning entities that use both the integrated planning approach and supplemental guidance. These entities should be selected to maximize two characteristic differences: (a) state and local use of the integrated planning approach, and (b) state and local use of supplemental guidance. An updated literature review should reveal the incentives and constraints to state and local policy adoption. Then, informed interviews with relevant officials in the sample states should identify the reasons leading to adoption of integrated planning and the constraints which have been encountered. Based on the literature and the interviews, the main reasons for differential adoption would be identified, and specific measures of the adoption of integrated planning and the reasons leading to adoption would be developed.

The developed measures would then be applied in both state and local jurisdictions to identify and document the reasons for differential adoption. Specific programs for technical assistance and information transfers could then be developed to advance the current status of uneven use of the integrated approach.

7.11 CURRENT MEANS OF IMPROVING PLANNING

Several steps can be taken to improve existing evacuation planning other than the development of new knowledge. The most significant improvement could be to adopt a systematic method for developing a plan, such as the process described in the hurricane program (Chapter 2). This method involves (1) identifying the nature of threats and their geographical distribution; (2) estimating the time available (i.e., from the time of detection of the hazard until the time when evacuation is not feasible); (3) calculating the time required to evacuate; and (4) developing guidelines to implement an evacuation, based on those estimates and other relevant data. The full details of this process are outlined in Chapter 2. This development method, however, can be implemented as a relatively simple procedure or a fairly complex one depending on the seriousness of the threat and available resources or expertise. Even if it is a simple effort, the benefits still can be significant because, simply by planning, officials will better understand the decision-making process.

The second step to improve the effectiveness of evacuation planning is to advance the application of existing knowledge of state-of-the-art hazard warning and emergency communication systems. Failure to notify the public-at-risk or to provide good information often causes poor or problematic evacuations. Considerable knowledge exists regarding the design of good warning systems, but it has not been systematically applied in the development of plans and operating procedures. Better warnings have had a dramatic impact on reducing fatalities from hurricanes; further improvements are still possible, and much could be done for a number of other hazards to increase citizen compliance with protective action recommendations, including evacuation.

Third, evacuation plans can be improved by upgrading the treatment of special or institutional populations. Although the technical basis for evacuating special populations still needs improvement, identifying the means and resources needed to evacuate institutions in high-risk areas is certainly feasible. This identification of special needs is often done after problems or near misses have been experienced. In addition, developing mechanisms for more effective communication with minority or other populations (who may be reluctant to evacuate) is also possible but is usually ignored. Such improvements can be made but are often not politically salient.

Finally, the development of more effective organizations to implement evacuation plans and make evacuation decisions is feasible at all levels of government. In many cases, this development can be done with little or no expenditure of additional resources, but it may involve redirecting planning efforts. However, this redirection will involve the development of new planning guidance and training materials to incorporate existing knowledge of organizational effectiveness in planning and emergency response.

7.12 CONCLUSIONS

Some issues concerning evacuation planning remain unresolved. The fact is that people who could have evacuated safely continue to die in disasters. The program of research identified in this report and better application of existing knowledge will contribute to reducing the potential losses from all disasters. Although issues regarding evacuation may be resolved, it should be noted that without the accompanying political accommodations there is little hope for implementation of policies. Taking this uncertainty into account and assuming that some planning will be better than ad hoc responses (considering anticipated increases in population density and in the number of threats and/or hazards), we identify four key areas of immediate attention.

Perhaps the most overriding issue concerns "the definition of the evacuation problem," including recognition of relevant hazards, interfaces between evacuation planning organizations, and the politicizing of planning. As noted previously, many of the current issues regard threats only recently defined as problems, thus requiring some immediate policy decisions. It takes time to adjust policies, but there may not be enough time when an earthquake is predicted, another volcano in the Cascades threatens to erupt, or a terrorist attack occurs at a major airport. The scientific community relies on evidence and caution which require time that may not be available. In certain other instances, local planners may not be informed about potential threats. For example, the military has specific, but possibly outdated, evacuation plans to cope with threats that may be neither reported to nor coordinated with local communities or officials. Furthermore, other agencies, such as the Red Cross, may have outdated plans to deal with today's range of evacuation threats such as hazardous material accidents. Thus, in many cases, there is little or no consensus on defining a problem or on deciding how agencies should deal with a problem.

Effective planning and decision making can be more problematic when organizational boundaries are crossed, particularly those lines of authority between local, state, and federal agencies. Should a federal agency necessarily oversee local matters when local officials may have greater awareness of needs and problems? This controversy has shown up in multiple emergencies--the need for generators to supply water following Mt. St. Helen's eruption, the problems of issuing reentry passes at perimeters of evacuated areas, the control of guardsmen duties, and so forth. How can flexibility be built into evacuation plans to consider multi-organizational participation? On the other hand, should political stances (e.g., opposition to nuclear power) be allowed to preclude safety measures (e.g., the implementation of evacuation plans for local communities at risk)? Opposition, as a political stance, may create greater hazards, in fact, some measures will always be opposed. There should be some consensus regarding contentions about the definition of the problem and its various solutions so that questions can be resolved without the constraint of "do nothing at all." Should a generic plan be the alternative for communities that refuse, as a political gesture, to institute plans? Support for such a generic plan could come from the acknowledge-

ment that public officials are responsible for public safety. As we move into the future, there will be more people at greater risk, an increasing number of hazards, and greater population heterogeneity. New solutions to defining the problems appear to be critically needed to implement general safety measures, such as evacuation plans for the public at large.

The second critical issue in evacuation planning concerns the physical characteristics of a hazard. Of those defined, the timing of events is the most important since it determines to whom, to what, and where the impacts occur. Both ends of the temporal spectrum must be examined. Future advances in technology may improve forecasting but the problems of short-time warning and rapid evacuation will remain. Furthermore, those hazards that can generate other hazards that could require protective actions other than evacuation have not been fully recognized by emergency planners. Again timing creates other problems if the event has a long time window. For example, the issues of convergence and restrictions that would keep the public returning to evacuated areas that may appear to be safe continue to pose problems for emergency officials.

Seasonal variations in the timing of an evacuation may create problems. An event that occurs during the height of the tourist season creates far greater demands on emergency planners than would an evacuation of the local populace only. Who pays the costs for evacuation of transients and tourists who may have additional needs because they are without normal kinship bonds and away from home?

In other situations, the ambiguity of the timing of an event impacts decision makers who do not want to evacuate unnecessarily. Still, advance notice affects the number of people who can be warned and evacuated successfully, as well the extent to which property can be protected. In addition, more advance notice is required to move special populations. It has been shown that people frequently hesitate for a variety of reasons before evacuating. The ability to successfully stage an evacuation is highly dependent on the good timing of decision making and information dissemination.

The third key issue concerns the impact that equity and the distribution of resources might have on evacuation decision-making. Who decides and how is it determined if warnings to evacuate are given in several languages; if special instructions are provide to people who are not supposed to be in the vicinity; or if added resources are used to evacuate institutional or special populations? How is it determined who or what areas get warned? How are resources allocated for evacuation planning when it is perceived they are not needed? Who sets such budget priorities? In earthquake planning, if people live in unsafe structures and cannot afford to move, who provides for them? These and other value judgements constrain or make evacuation planning difficult.

The fourth issue concerns providing effective information flows to the public. Much is known about information flows, but evacuation experience continues to illustrate problems with information processes. For example, it has been demonstrated that information to support an

evacuation should be consistent for greatest effectiveness. How do officials keep information factual when media personnel are actively seeking competing or different viewpoints or independently interpreting data, thus potentially misinforming the public? How can the media be encouraged not to sensationalize an event? How can technical information be relayed effectively to the public when the media assumes the roles of information interpretation and gatekeeping? What mix of information about an event maximizes adaptive evacuation behaviors? This area requires further clarification to overcome ambiguous evidence derived from a varied set of past research efforts.

Despite these concerns, it can be concluded that, over the past decade, evacuation planning has become more sophisticated and advanced. Progress has been made in at least four major ways. First, evacuation planning for some hazards has integrated physical risk studies with quantitative evacuation traffic modeling and behavioral research to produce comprehensive planning guidance. The best examples of this approach are found in hurricane evacuation planning and nuclear power plant evacuation planning. For the former, extensive modeling of hurricane storm surge defines the maximum levels of water inundation. Vulnerability studies identify populations at risk, and behavioral studies are used to estimate evacuation departures and destination. By using vulnerability and behavioral data combined with a quantitative evacuation time estimate, local emergency planners can decide when they must make an evacuation decision and which areas to evacuate. This type of approach is less well developed for other hazards, although FEMA is moving in the direction of initiating similar programs for some other hazard types.

Second, the adoption of an integrated or generic emergency management approach has and will further bolster the expediency of evacuation planning. Given the integrated scientific approach being pursued, integrated planning will eliminate many overlapping planning tasks among hazard types. Furthermore, integration will encourage more flexible emergency evacuation capabilities that will apply to most conceivable contingencies.

Third, over the past 10 years, most aspects of evacuation logistics have been defined and researched and, as a result, are well understood. Withstanding the issues raised in the subsequent section, the knowledge of how to move small of fairly large numbers of people is fairly well developed. This does not mean this knowledge has been implemented or adopted in all evacuation plans, or that some hazard-specific uncertainties have been eliminated. Overall, however, we know the resource requirements for evacuating most populations from threatened areas in a reasonable amount of time.

Finally, there are indications that the local implementation of evacuation procedures has improved. Each year thousands of people are successfully evacuated from floods and hazardous material accidents. Evacuation rates from high-risk coastal areas preceding hurricanes are very high, and deaths from hurricane surge have been significantly reduced. Many specific success stories could be cited.

The success stories, however, must be balanced with the problems identified earlier. Evacuation planning, as well as other forms of emergency planning, is an ongoing and evolving process. The extent to which existing knowledge can be incorporated into planning and to which new research can resolve remaining issues and constraints will determine how rapidly that evolution occurs.

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APPENDIX A

CODING FORM

DRAFT

SAMPLE CODING SHEET

Authors

Year published

Title

Journal; publisher; etc.

Journal Vol. and No.

Location (if applicable)

Pages or Chapter

Remarks:

ABSTRACT:

Key findings:

(1)

(2)

(3)

(4)

CODING:

Study characteristics:
- Type of data collection:
- Sampling unit:
- Level of analysis:
- Number of incidents that provoke response:
- Number of geographic areas/time periods:
- Evacuation topics emphasized:
- Policy recommendations? Supported?

APPENDIX B

SUMMARY OF EVACUATION ISSUES BY APPLICABLE HAZARD TYPE

APPENDIX B

SUMMARY OF EVACUATION ISSUES BY APPLICABLE HAZARD TYPE

We have summarized the applicability of each issue to each specific hazard. This is based on evidence collected as part of task four. It is quite possible that some issues also apply to other hazards and are not reported here.

Hazard key:

hur - hurricane, eq - earthquake, tsu - tsunami, fld - flood, tor - tornado, vol - volcano, dam - dam failure, npp - nuclear power plant accident, fshm - fixed site hazardous material accident, thm - transportation hazardous materials accident, crs - crisis situation

Physical Hazard Characteristics

Uncertainty in ability to specify hazard parameters.

- Location - hur, eq, tsu, fld, tor, vol, npp, fshm, thm, crs
- Timing - hur, eq, vol
- Magnitude - eq, fld, vol, npp, fshm, thm, crs
- Effects - npp
- Secondary Hazards - hur, eq, vol

Uncertainty in ability to detect hazards.

- Scientific ability - tsu, dam, fshm, thm
- Lack of physical cues - npp

Hazard Characteristics constrain evacuation effectiveness.

- speed of onset - eq, fld, tsu, vol, fshm, thm, crs

Planning Increases the threat or risk of hazard.

- planning increases the likelihood of an event - npp, crs

Warning Characteristics

Uncertainty in ability to alert.

- Lack of warning systems - eq, dam, fshm, thm
- Timing of warnings - fld, tsu, npp fshm, thm
- Information withholding - eq, npp, fshm
- Inadequate communication - fld, npp, fshm, thm
- Risk not revealed - npp, fshm, thm

- Warnings not issued to certain groups - hur, fld, npp
- Sirens not heard - tsu, npp, fshm

Information constrains evacuation.

- Special terminology - hur, tor, npp
- Probabilistic information - hur, eq
- Multiple messages - hur, eq, vol
- Inadequate content - fld, npp, crs
- Credibility - npp, crs
- Frequency - hur
- Siren use - tsu, npp, fshm

Social Issues

Social factors color risk perceptions.

- Mitigation measures - hur, dam
- Prior experience - hur, tor
- Depersonalization of threat - eq
- Fear of radiation - npp
- Denial of hazard - fld, fshm
- Denial of need for preparedness - crs
- False alarms - hur, eq, tsu, tor, npp, crs

Factors color the ability to receive warnings.

- Culture and ethnicity - eq
- Disbelieve ability to detect or predict - eq, crs
- Lack understanding of risk - fld, hur, tsu, vol

Factors affecting the ability to evacuate.

- Economic resources - eq
- Special or institutional populations - hur, npp, crs

Organizational Issues

Planning Elements are inadequate.

- Coordination of planning is lacking - hur, eq, fshm, crs
- Inadequate planning for shelters - hur, npp fshm, thm, crs
- Lack of plans - eq, fld, tor, dam, npp, sdhm, thm, crs
- Planning for secondary hazards - hur, fld, vol, npp
- Definition of emergency planning zones (epz) - npp
- Plans for institutional facilities and special populations - hur, eq, npp, fshm, crs
- Planning for reentry - hur, npp, crs
- No support for planning - hur, npp, crs
- Planning for emergency resources to support evacuees - crs
- Planning for medical and health care of evacuees - crs

- Planning for extended evacuations - crs
- Planning uses the wrong assumptions - crs

Training of evacuation personnel is inadequate. - npp, thm

The technical basis for evacuation planning is inadequate.

- Evacuation time estimates are inaccurate - hur, npp, crs
- Plans will lead to unnecessary evacuation - hur
- Organizations for developing plans are lacking - fshm, thm
- Organizations with responsibilities downplay the hazard - eq, dam
- Knowledge not transferrable - npp, crs
- Dissemination of technical knowledge is poor - all
- Population at risk is unknown - thm

Response Issues

Physical factors constrain evacuation.

- Population is too dense to evacuate - hur, eq, npp, crs
- Population in areas with seasonal peaks - hur, npp
- Boats will interfere with island evacuation - hur
- Traffic accidents will constrain evacuation - hur, npp, crs

Public behavior.

- People will hold parties instead - hur, eq, fld
- Evacuation shadow - eq, npp
- Panic - eq, npp, crs
- Convergence - fld, tsu, vol, thm
- Spontaneous evacuation - npp, crs
- Aberrant behavior - npp, crs
- People won't use specially designated routes - npp
- Stress will occur due to evacuation - npp, fshm, crs
- People won't obey officials - npp, crs
- People wont evacuate for long periods of time - vol, crs
- People don't know how to evacuate - eq, fld, tor, npp, thm
- People will shelter instead - crs
- People will not go to designated host areas - crs
- Total social chaos - crs

Emergency worker behavior.

- Role abandonment - npp, crs
- Denial of evacuees - crs
- Erosion of leadership - crs
- No outside support - crs

Evacuation not perceived as a public good.

- Evacuation puts people at greater risk - hur, npp, fshm, crs
- People have right to stay - hur, vol
- Evacuations create liabilities - all

APPENDIX C

SUMMARY OF BEHAVIORAL DATA ON EVACUATION

Table C.1. Data sources for behavioral surveys on evacuation

Event	Source
Denver Flood	Drabek and Stephenson, 1971
Big Thompson Flood	Gruntfest, 1977
Westville Flood	Perry and Mushkatel, 1984
Sumner Flood	Perry et al., 1981
Valley Flood	Perry et al., 1981
Fillmore Flood	Perry et al., 1981
Snoqualmie Flood	Perry et al., 1981
Rapid City Flood	Mileti and Beck, 1975
Mt. St. Helens Volcano	Perry and Greene, 1983
Atlanta Flood	Leik et al., 1981
Boise Flood	Leik et al., 1981
Wheeling Flood	Leik et al., 1981
Sedona Flood	Leik et al., 1981
Clarksburg Flood	Leik et al., 1981
Rochester Flood	Leik et al., 1981
Hurricane Eloise	Windham et al., 1977
Hurricane Eloise	Baker et al., 1976
Hurricane Camille	Wilkenson and Ross, 1972
Hurricane David	Leik et al., 1981
Hurricane Frederick	Leik et al., 1981
Hurricane Carla	Moore et al., 1964
Mississauga Chemical Accident	Burton, 1981
Railsville Chemical Accident	Perry and Mushkatel, 1984

Table C.2. Warning and evacuation rates

Event	Percent of respondents	
	Warned	Evacuated
Quick Response		
Big Thompson flood	30	32
Westville flood	100	35
Sumner flood	86	48
Valley flood	98	39
Fillmore flood	72	48
Snoqualmie flood	98	37
Mt. St. Helens eruption	93	-
Atlanta flood	81	7
Boise flood	42	0
Wheeling flood	73	0
Sendona flood	63	24
Clarksburg flood	89	21
Rochester flood	38	48
Mississauga	100	98
Extended response		
Hurricane David	97	38
Hurricane Frederick	98	34
Hurricane Carla	-	65
Mt. St. Helens ashfall	98	NA

Table C.3. Source of first warning

Event	Source of warning	Percent warned
Big Thompson flood	Sheriff	45
	Friend	20
	Stranger	20
	Police Dispatch	15
	Telephone	52
	Loudspeaker	4
	Face to face	21
	Siren	5
Denver flood	Authorities	19
	Friend, etc.	28
	Mass media	52
Combined flash floods*	Authorities	49
	Friends, etc.	33
	Mass media	5
	Environmental cues	14
Mt. St. Helens (ash)	Personal	52
	Radio	34
	Television	12
Mt. St. Helens (mudflow)	Personal	37
	Emergencies authorities	46
	Mass media	10
	Cues	6
Mississauga	Personal	11
	Media	44
	Police	43

*Source: Perry et al., 1981.

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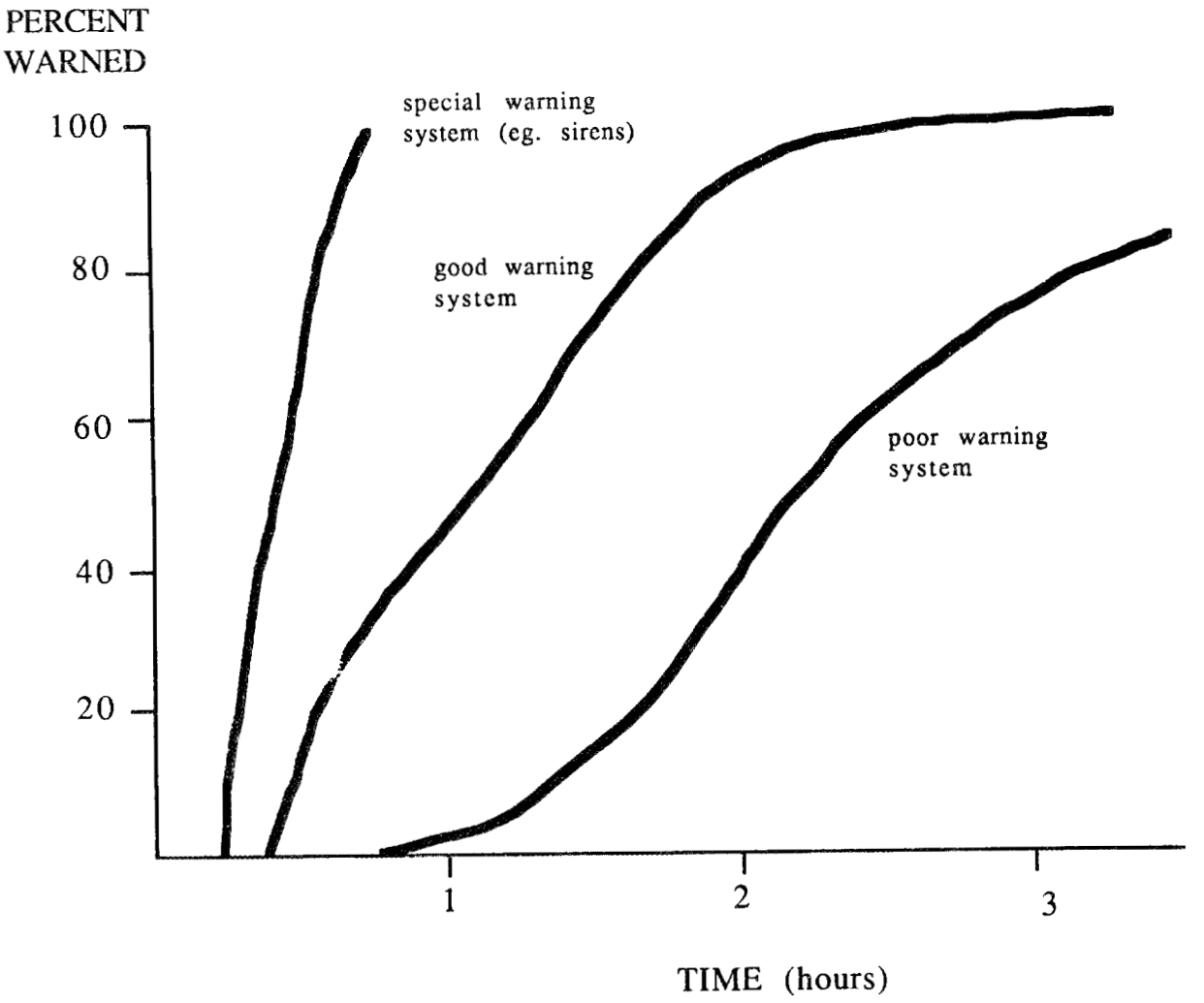

Figure C-1. Warning times given different systems.

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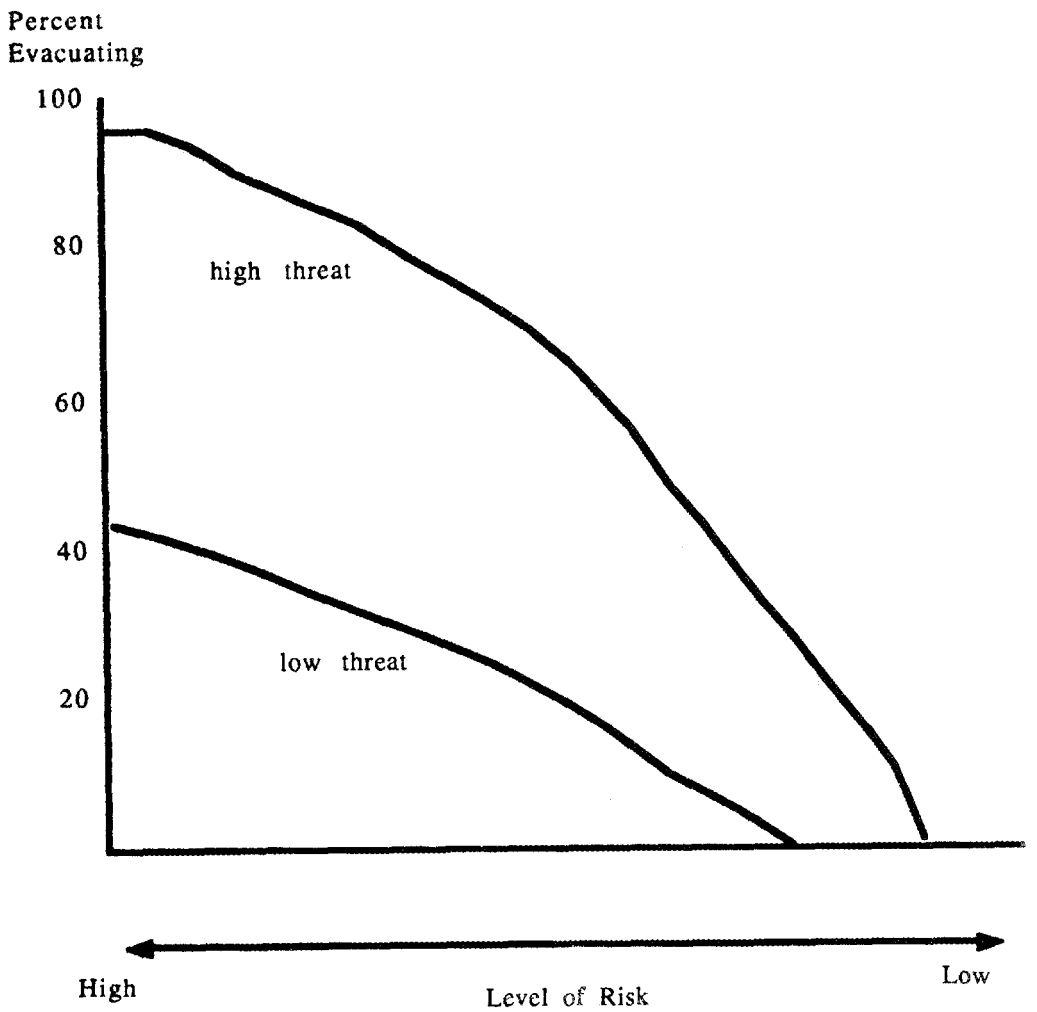

Figure C-2. Generalized relationship between risk and evaluation.

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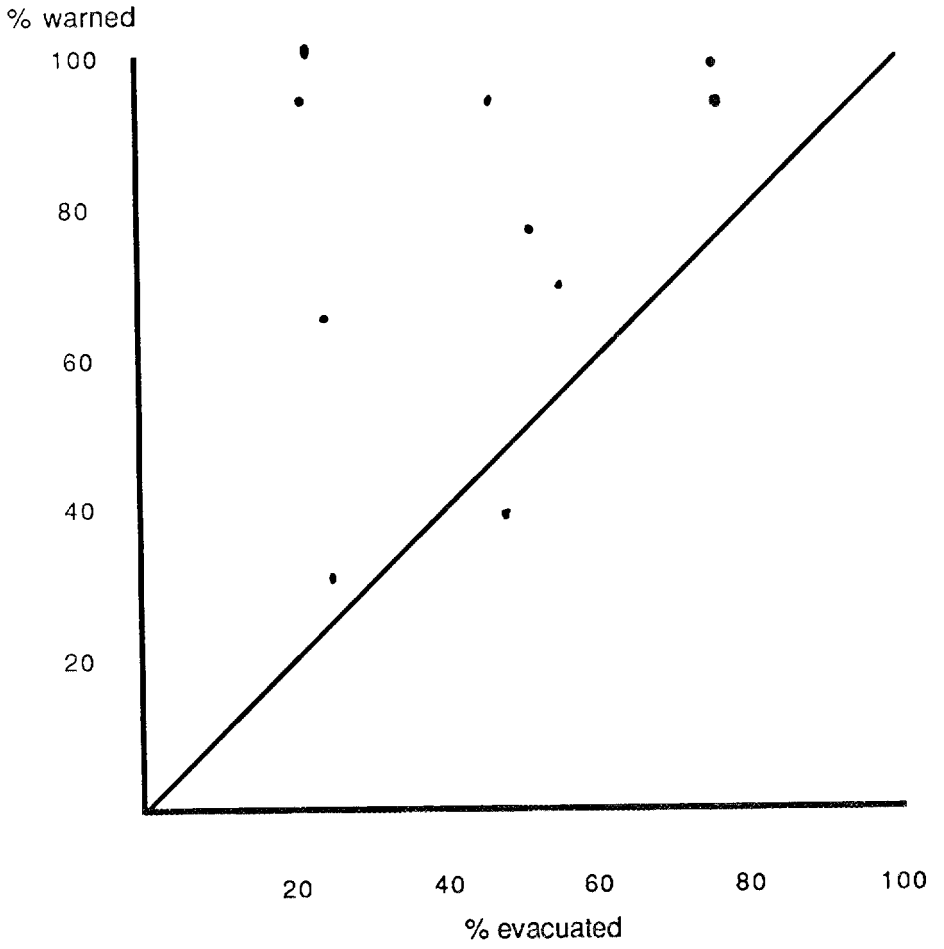

Figure C-3. Warning versus evacuation rates.

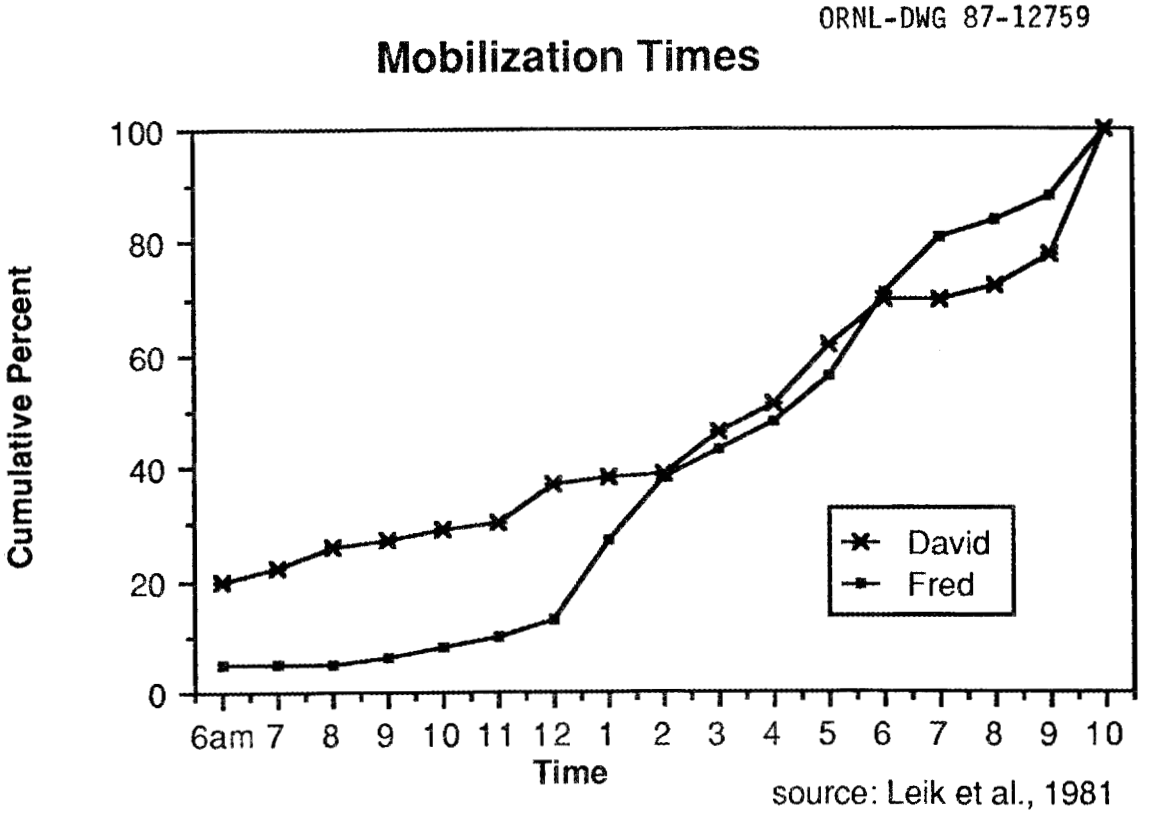

Figure C-4. Evacuation departure times for two hurricanes.

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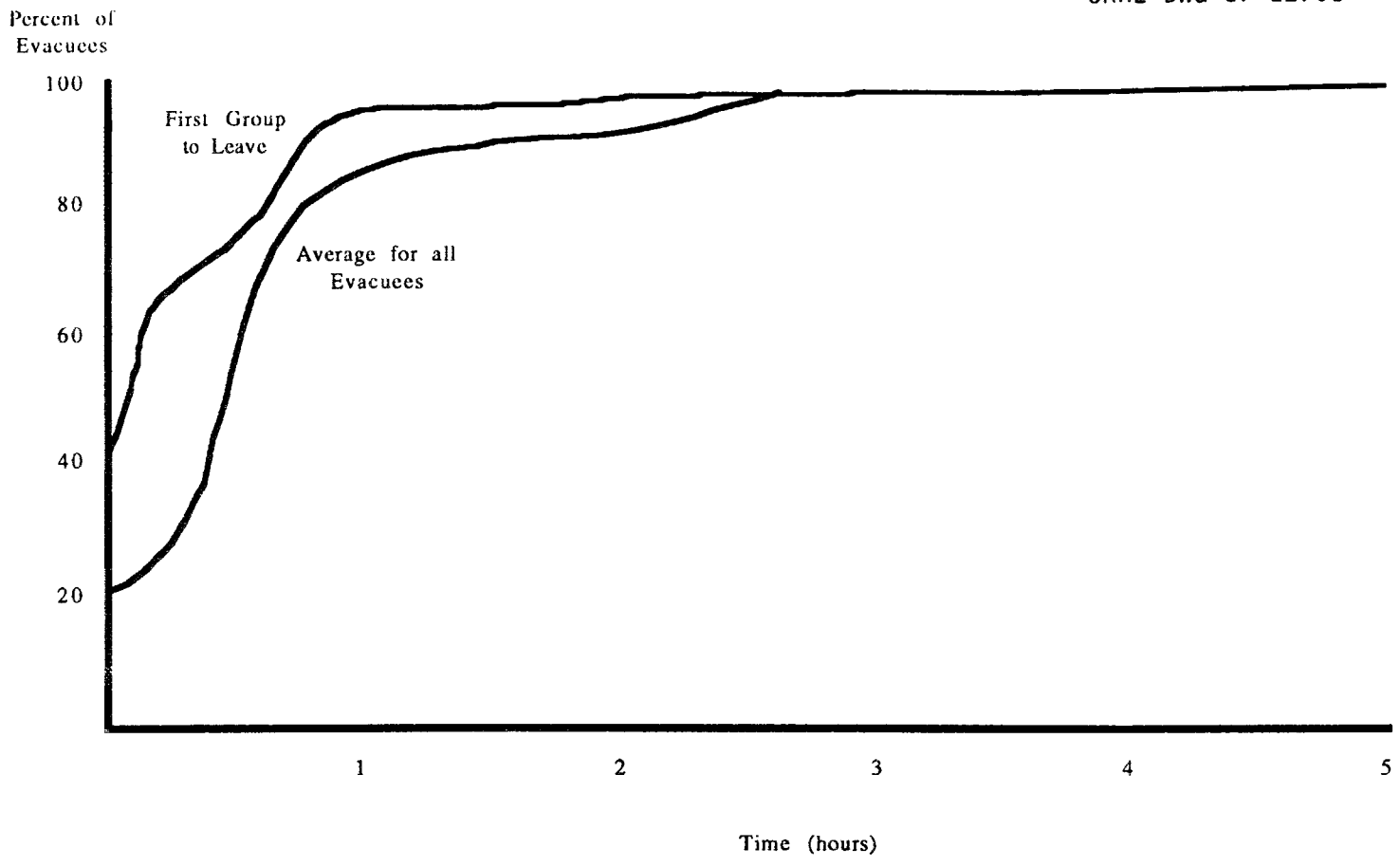

Figure C-5. Mobilization times at Mississauga. Source: Burton, 1981.

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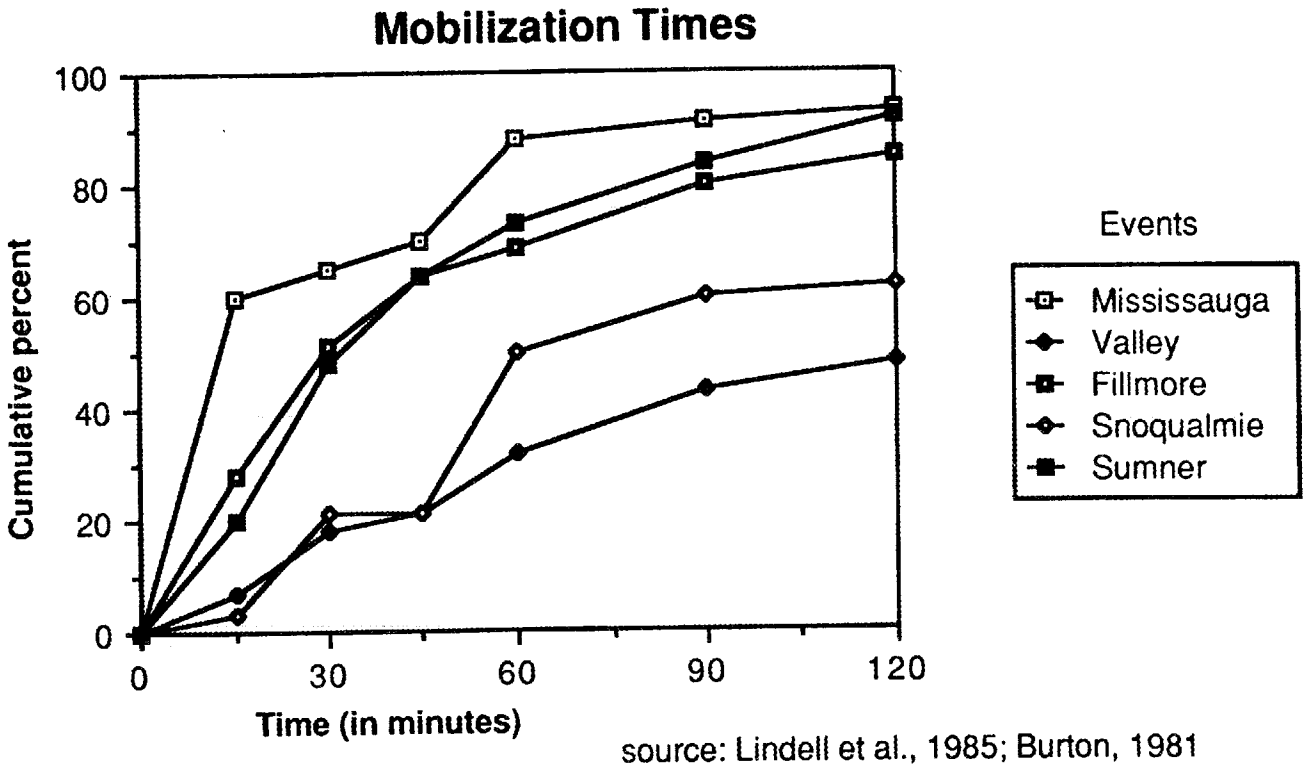

source: Lindell et al., 1985; Burton, 1981

Figure C-6. Mobilization times in five floods.

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Interagency Agreement: FEMA No. EMW-84-E-1737; DOE No. 40-1457-84

The purpose of this research was to assess issues and criticisms of evacuation planning for all hazards under an integrated emergency management concept and to review research that addresses those issues. The work identifies gaps in knowledge about evacuation planning issues and research that can address these gaps. Over the past decade, evacuation planning has become more sophisticated and advanced. The adoption of an integrated or generic emergency management approach has bolstered the expediency of evacuation planning. Most aspects of evacuation logistics have been defined and researched and, as a result, are well understood. The local implementation of evacuation procedures has improved, but could be further improved with a better application of existing knowledge. Some issues concerning evacuation planning still remain unresolved.

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