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EVALUATION OF THE EMERGENCY WARNING SYSTEM AT THE FORT ST. VRAIN NUCLEAR POWER PLANT

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ABSTRACT

The Fort St. Vrain power plant is the only high-temperature gas-cooled reactor (HTGR) in commercial operation in the United States. All commercial reactors, regardless of technology, must conform to Nuclear Regulatory Commission emergency planning regulations developed in light of *Clarification of TMI Action Plan Requirements* (NUREG-0737). This report analyzes the applicability of warning-related planning requirements to HTGRs and evaluates the strengths and weaknesses of warning procedures at Fort St. Vrain.

Specific criteria for radiological emergency preparedness plans are presented in *Criteria for Preparation and Evaluation of Radiological Emergency Response Plans and Preparedness in Support of Nuclear Power Plants* [NUREG-0654/FEMA-REP-1 (Rev. 1)] and specified by "Final Regulations on Emergency Planning" (*Federal Register*, Vol. 45, No. 162, Part VIII, Aug. 19, 1980). Public Service of Colorado, which operates the Fort St. Vrain Facility, has challenged the applicability of certain requirements, which, therefore, have not been included in their Radiological Emergency Response Plan. Three of these areas of contention are examined in the report:

1. Requirements for an early warning capability,
2. Responsibility for the warning system, and
3. Public information programs.

Second, a conceptual model of warning system effectiveness is developed and utilized to evaluate the Fort St. Vrain system. Suggestions on how warnings can be improved are made. Implications of the Three Mile Island (TMI) accident are also discussed in the context of radiological warning systems.

The study concludes that, in light of assumptions about HTGR accident characteristics and based on social criteria, the NRC should define new emergency standards for Fort St. Vrain. The existing warning system at Fort St. Vrain is shown to be adequate to ensure public safety in the event of an emergency. Subsequent to the completion of this study, Public Service of Colorado decided to install an early warning system to alert the public to an emergency, thus complying with NRC regulations. Nevertheless, that action

does not invalidate the findings of this study, and they remain relevant to future regulatory decisions on emergency planning for HGTRs and other types of reactors.

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1. SCOPE OF WORK

1.1 PROBLEM

The Fort St. Vrain nuclear power plant, operated by Public Service of Colorado (PSC), is the only high-temperature gas-cooled reactor (HTGR) in commercial operation in the United States. The more common light-water reactor (LWR) is based on light-water cooling technologies. The Nuclear Regulatory Commission (NRC) is charged with assessing the adequacy of emergency preparedness and response plans of all licensees, regardless of the type of reactor. Together with the Federal Emergency Management Agency (FEMA), NRC has developed requirements for local, state, and licensee emergency plans. NUREG-0654/FEMA-REP-1 (Rev. 1), *Criteria for Preparation and Evaluation of Radiological Emergency Response Plans and Preparedness in Support of Nuclear Power Plants*, contains 16 standards,* which must be included in all plans. These standards, however, were developed in the context of *Clarification of TMI Action Plan Requirements* (NUREG-0737). Thus, they represent emergency standards based on a 1000-MW LWR. There is some question of which of these criteria are or should be applicable to the Fort St. Vrain power plant, because of critical differences in HTGR and LWR technologies. Since the existing emergency plans of Fort St. Vrain and the Colorado State Division of Disaster Emergency Services (DODES) did not fully

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*Specified by "Final Regulations on Emergency Planning," *Federal Register*, Vol. 45, No. 162, Part VIII (Aug. 19, 1980).

conform with NUREG-0654/FEMA-REP-1 (Rev. 1), the general adequacy of planning and of response capabilities at Fort St. Vrain has been brought into question.

1.2 OBJECTIVES OF THE STUDY

This evaluation of the Fort St. Vrain emergency-response capability had two objectives:

1. To help resolve the points of contention between PSC and NRC regarding differences between the Fort St. Vrain plan and NRC requirements.

2. To evaluate the Fort St. Vrain Radiological Emergency Response Plan based on considerations which are distinct from the NRC criteria. These considerations are based on (1) social science research on the management of and response to natural and man-made hazards and on (2) lessons learned from social science research after the accident at Three Mile Island (TMI).

1.3 APPROACH AND METHODS

These steps were followed:

1. Issues or points of contention were identified by reviewing correspondence between NRC and PSC.

2. These issues were discussed with representatives of PSC and the Colorado DODES during a site visit.

3. Issues were analyzed in light of previous research findings and knowledge of disaster management.

4. Evaluation criteria for the warning portion of the radiological emergency plans were developed. This evaluation focused on the behavioral science aspects of the warning plans.

5. The Fort St. Vrain plan was reviewed in light of the evaluation criteria.

6. Lessons from the TMI accident that apply to warnings were summarized.

Section 2 of this report reviews the issues. Section 3 brings previous research to bear on the issues and attempts to resolve the issues accordingly. Section 4 discusses findings from TMI and the implications for radiological warning systems. Section 5 presents the conclusions of the study. References and a bibliography on warning systems for radiological emergencies are also included.

2. ISSUES

This section reviews three issues that have surfaced during the review of the Fort St. Vrain Radiological Emergency Response Plan. The issues concern early warning capabilities, responsibility for warnings, and public information. All three relate to a broader issue: How adequate are emergency planning efforts for responding to a potential emergency?

2.1 EARLY WARNING CAPABILITY

NUREG-0654/FEMA-REP-1 (Rev. 1) (p. 45) specifies the following evaluation criteria for public notification:

> Each organization (Licensee, State, Local) shall establish administrative and physical means, and the time required for notifying and providing prompt instructions to the public within the plume exposure pathway Emergency Planning Zone [EPZ] (Appendix 3).

The Appendix 3 referred to in the quotation specifies the minimum criteria for a warning system:

> Criteria for Acceptance
>
> 1. Within the plume exposure EPZ the system shall provide an alerting signal and notification by commercial broadcast (e.g., EBS) plus special systems such as NOAA [National Oceanic and Atmospheric Administration] radio. A system which expects the recipient to turn on a radio receiver without being alerted by an acoustic alerting signal or some other manner is not acceptable. [Here EBS means emergency broadcast system.]

2. The minimum acceptable design objectives for coverage by the system are:

   a. Capability for providing both an alert signal and an informational or instructional message to the population on an area wide basis throughout the 10 mile EPZ, within 15 minutes.

   b. The initial notification system will assure direct coverage of essentially 100% of the population within 5 miles of the site.

   c. Special arrangements will be made to assure 100% coverage within 45 minutes of the population who may not have received the initial notification within the entire plume exposure EPZ.

   The basis for any special requirements exceptions (e.g., for extended water areas with transient boats or remote hiking trails) must be documented. Assurance of continued notification capability may be verified on a statistical basis. Every year, or in conjunction with an exercise of the facility, FEMA, in cooperation with the utility operator, and/or the State and local governments will take a statistical sample of the residents of all areas within about ten miles to assess the public's ability to hear the alerting signal and their awareness of the meaning of the prompt notification message as well as the availability of information on what to do in an emergency. The system plan must include a provision for corrective measures to provide reasonable assurance that coverage approaching the design objectives is maintained. The systems shall be operable no later than July 1, 1981. The lack of a specific design objective for a specified percent of the population between 5 and 10 miles which must receive the prompt signal within 15 minutes is to allow flexibility in system design. Designers should do scoping studies at different percent coverages to allow determination of whether an effective increase in capability per unit of cost can be achieved while still meeting the objective of item 2.a. above.

3. Public Notifications

   A prompt notification scheme shall include the capability of local and State agencies to provide information promptly over radio and TV [television] at the time of activation of the alerting signal. The Emergency Plans shall include evidence of such capability via agreements, arrangements or citation of applicable laws which provide for designated agencies to air messages on TV and radio in emergencies. Initial notifications of the public might include instructions to stay inside, close windows and doors, and listen to radio and TV for further instructions.

The critical aspects of these requirements are those that necessitate designing a warning system that covers a 10-mile (∿16-km) radius in such a manner that the message is disseminated within 15 min, achieving 100% coverage within a 5-mile (∿8-km) radius. Requirements for the Fort St. Vrain facility have been modified to require only a 5-mile (∿8-km) EPZ, and thus the 10-mile (∿16-km) requirement does not apply. While the utility is now in compliance with the 15-min requirement, an examination of this issue is still warranted.

PSC did not comply with this early warning capability, because they felt that under the worst probable accident, 20 h would elapse before any radioactive material released would cross the site boundaries. This time would be ample, PSC contended, to detect and classify the accident, initiate emergency procedures, notify the public, and evacuate if necessary.

Further support for the PSC position rested on economic considerations. Estimates indicated that almost $600,000 would be needed to design and set up a siren system that met specifications. A tone-alert radio system distributed to every residence and business could meet the requirement at considerably less cost. Experience at other reactors suggests that warning systems that comply with the 15-min criterion for a 10-mile (∿16-km) EPZ can cost as much as $2 million. This is not justified, according to PSC, in light of the risks, since design-basis and maximum hypothetical accidents analyzed in PSC's Final Safety Analysis Report (FSAR) show that offsite doses would not reach radiation levels that warrant protective actions.

Finally, PSC contended that the population density is too low in the surrounding area to justify such an expensive system. Furthermore, it was pointed out that the people living in the 5-mile (∿8-km) EPZ are apparently satisfied with the existing procedures, because no complaints had surfaced in recent public forums concerning emergency preparedness.

The warning system originally in place at Fort St. Vrain relied chiefly on media broadcasts on commercial radio and TV stations and the EBS and NOAA radio systems. In addition, door-to-door notification of people living in the 5-mile (∿8-km) EPZ would be conducted by the county sheriff if protective actions should be recommended.

These door-to-door notifications would most likely be carried out only in a sector of the EPZ in which evacuation would be recommended. Estimates are that 100% notification could be achieved within a maximum of 6 h after the emergency was first detected. As a result of a recent field test, the time needed to conduct door-to-door notification in a 90° sector was estimated to be 2 h. This time could be reduced with more personnel and practice. Figure 2.1 compares the NRC/FEMA criteria warning system with the original capabilities at the Fort St. Vrain facility.

In February 1982, 1077 tone-alert radios were installed in residences and businesses within the 5-mile (∿8-km) EPZ. Three households refused the equipment. The need for this system is further analyzed by this study.

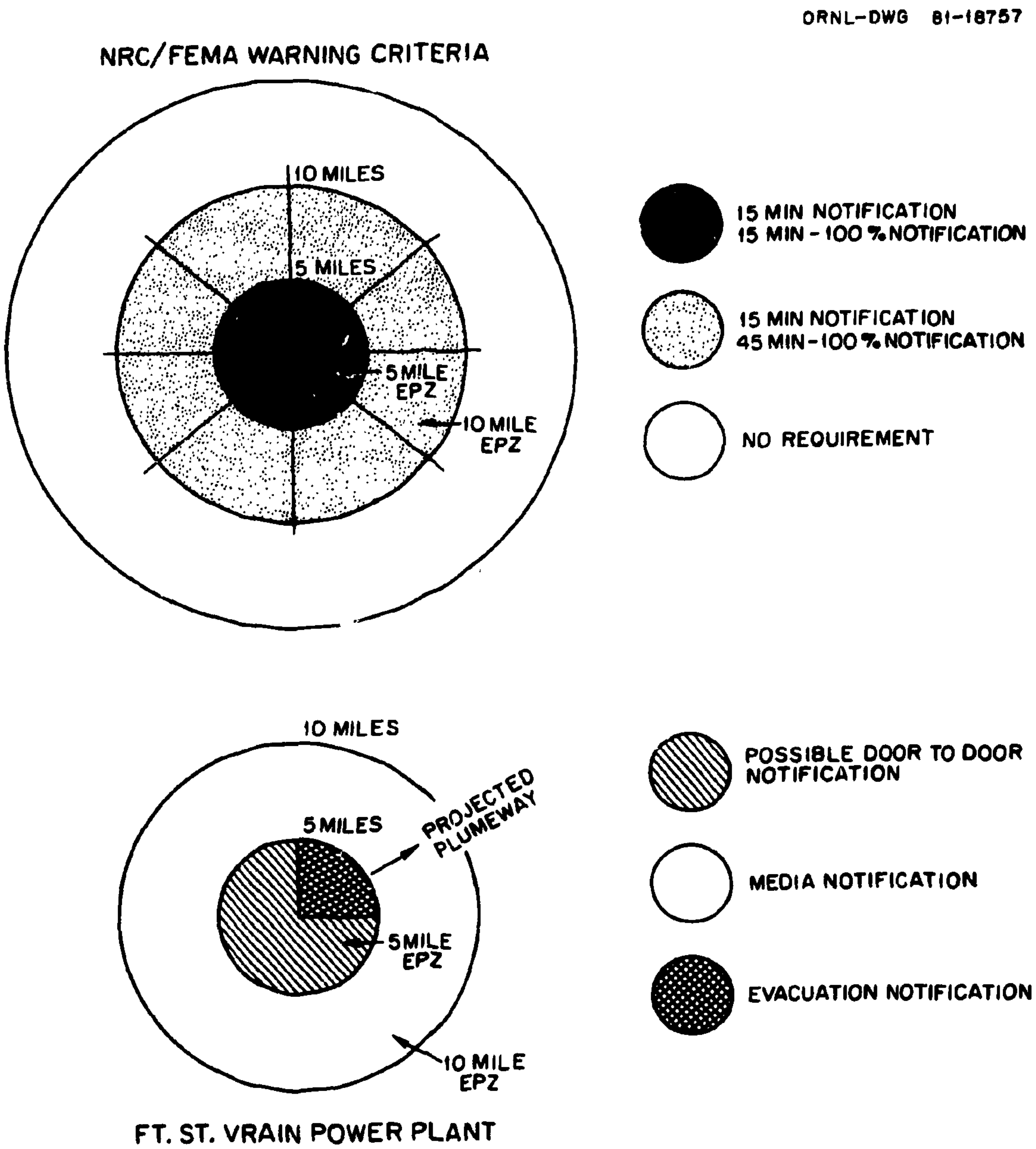

Fig. 2.1. Warning comparisons.

2.2 WARNING RESPONSIBILITY

The warning system briefly described in the previous subsection is currently the full responsibility of the Colorado DODES. This reflects the mutual position of DODES and PSC that it is the government's responsibility, and not the licensee's, to warn the public in the event of an emergency.

NUREG-0654/FEMA-REP-1 (Rev. 1) states, to the contrary:

> It shall be the licensee's responsibility to demonstrate that such means (for warning the public) exist, regardless of who implements the system. It shall be the responsibility of the State and local governments to activate such a system.

The position taken by PSC may not conform to the spirit of this stated requirement, depending on how one defines "demonstrate." Whether this portion is inherently bad or good or even relevant requires further investigation.

2.3 PUBLIC INFORMATION

A critical element in most emergency-response strategies is a public information program. Adaptive behaviors in emergencies are actions that reduce the likelihood of being injured, killed, or experiencing damage. To induce adaptive behavior, people must know how to respond. It is unlikely that people will acquire such information on their own. In response to this concern, NUREG-0654/FEMA-REP-1 (Rev. 1) (p. 49) contains the following requirements related to public education:

> Each organization shall provide a coordinated periodic (at least annually) dissemination of information to the public regarding how they will be notified and what their actions should be in an emergency. This information shall include, but not necessarily be limited to:
>
> a. educational information on radiation;
>
> b. contact for additional information;
>
> c. protective measures, e.g., evacuation routes and relocation centers, sheltering, respiratory protection, radioprotective drugs, and
>
> d. special needs of the handicapped.
>
> Means for accomplishing this dissemination may include, but are not necessarily limited to: information in the telephone book; periodic information in utility bills; posting in public areas; and publications distributed on an annual basis.
>
> The public information program shall provide the permanent and transient adult population within the plume exposure EPZ an adequate opportunity to become aware of the information annually. The programs should include provision for written material that is likely to be available in a residence during an emergency. Updated information shall be disseminated at least annually. Signs or other measures (e.g., decals, posted notices or other means, placed in hotels, motels, gasoline stations and phone booths) shall also be used to disseminate to any transient population within the plume exposure pathway EPZ appropriate information that would be helpful if an emergency or accident occurs. Such notices should refer the transient to the telephone directory or other source of local emergency information and guide the visitor to appropriate radio and television frequencies.
>
> Each organization shall conduct coordinated programs at least annually to acquaint news media with the emergency plans, information concerning radiation, and points of contact for release of public information in an emergency.

The NRC has questioned whether PSC has fulfilled these requirements and whether their public information efforts are adequate.

PSC currently disseminates information on the Radiological Emergency Response Plan to the public within the 5-mile (∿8-km) EPZ through an information brochure (Appendix B). The brochure is available in both English and Spanish. In addition, the Fort St. Vrain power plant maintains a visitor center, which is geared toward providing information about the reactor. PSC has also developed a video tape, titled "Just in Case," that is utilized to help educate local support agencies and shown at public meetings at the visitor's center. The tape is available for viewing at the center. Information tours are held annually for the media.

3. RESOLVING THE ISSUES

This section attempts to analyze objectively the three issues presented in the previous section and to recommend possible solutions to the problems raised by the issues.

3.1 EARLY WARNING CAPABILITY

The general question underlying the issue of early warning capability is this: what constitutes an adequate system for warning the public about an emergency at the Fort St. Vrain facility? Since adequacy is difficult to measure in this context, a fuller elaboration on the purpose of warning systems is desirable.

3.1.1 An "integrated" warning system

The aim of any warning system is to alert as many people as possible to the likelihood and consequences of a potential, impending disaster and to tell them what protective actions to perform. Warning system adequacy can therefore be measured by the extent of actions taken that would result in reduced damages and casualties in the event of an emergency and in increased emergency preparedness activities (Mileti, Hutton, and Sorensen 1981).

An "integrated" warning system, illustrated in Fig. 3.1, performs three basic functions (Mileti 1975): evaluation, dissemination, and response.

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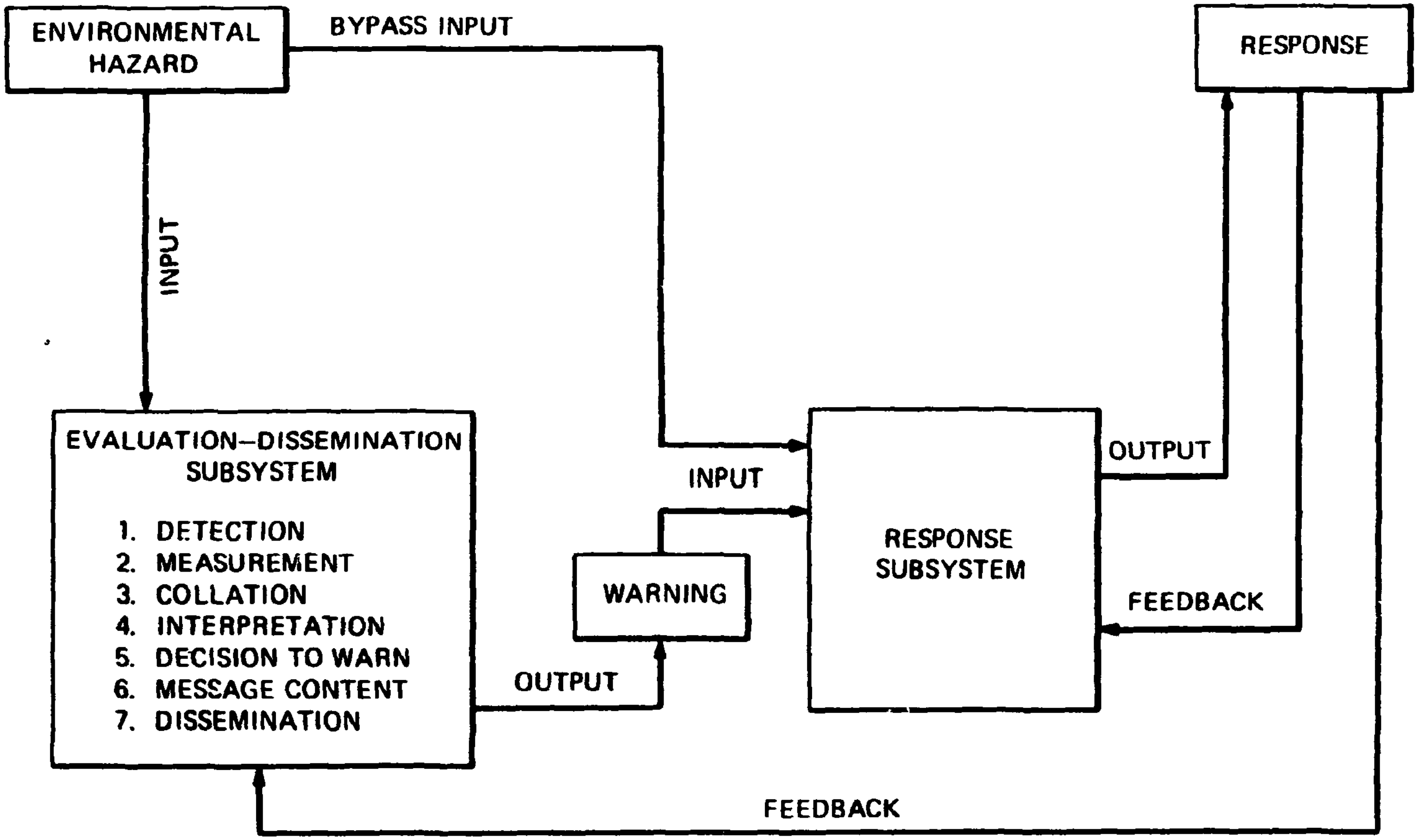

Fig. 3.1. An integrated warning system (Mileti, Hutton, and Sorensen 1981).

Evaluation is the estimate of threat from a hazard to people in an area that is at risk. The processes involved in evaluation are detection, measurement, collation, and interpretation of available technical information about the likelihood of and threat (risks) posed by the hazard. Dissemination of a warning to people in danger encompasses deciding whether or not the risks warrant alerting the public to the possible danger, explaining them, and suggesting what actions to take. Response is the taking of adaptive action by people receiving the warnings. Actions, however, are influenced by people's interpretations of warnings. These interpretations are shaped by many social, economic, pyschological, and situational factors.

The adequacy of a warning system is based on having effective linkages between the three system functions. It is based neither solely on the ability to detect nor on warning hardware and equipment. The dissemination-response linkage is vital to achieving adequate and effective warnings, yet it is the least understood and the weakest link in most warning systems (Mileti, Hutton, and Sorensen 1981).

3.1.2 Behavioral considerations for warning systems

Numerous behavioral science studies on the effectiveness of and human response to warnings have been conducted by sociologists and geographers (Mileti 1975, McLuckie 1974, Sorensen and Gershmehl 1980, Gruntfest 1977). Most of these studies have focused on warnings of impending natural disasters, such as floods, hurricanes, volcanoes, tsunamis, or earthquakes.

Several have dealt with the TMI nuclear power plant accident (Flynn 1981). The synthesis that follows is generated from the findings of these investigations. While they represent a consensus of facts, they may not hold true for every warning situation. Nevertheless, these observations provide a reasonable basis for evaluating warning system effectiveness from a behavioral perspective.

Figure 3.2 graphically summarizes a range of factors that influence human response to warnings. Because warning effectiveness has been defined in terms of the success of the warning in prompting adaptive behavior, such factors influence system adequacy.

The single dominant factor that influences people's response to a warning is, simply, whether or not they believe the message. Believability, however, has been found to be influenced by a number of variables both internal and external to the warning system. Starting at the left side of Fig. 3.2, examples of these relationships can be provided.

The nature of a warning can be described by the following dimensions:

1. its source,
2. the mode or channel by which it is communicated, and
3. the contents of the message.

Studies have shown that warnings from an "official" emergency management source are generally more effective than warnings from an unofficial

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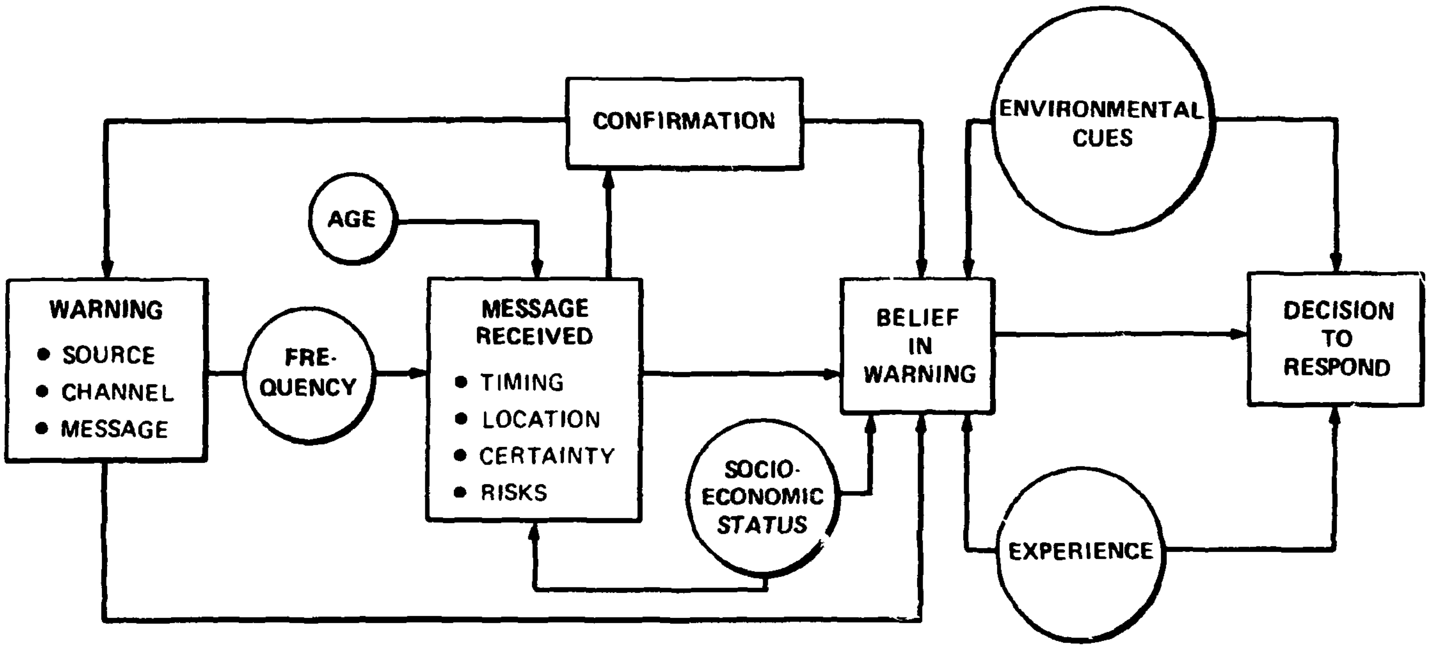

Fig. 3.2. Behavioral considerations for warning system evaluation.

source. Warnings issued by local official sources such as police are more effective than warnings from the federal government. Minorities or low-income groups, however, are more skeptical of warnings from a government source. One problem is that people often confuse source with channel; a message coming over TV or radio may not be seen as official despite its origin (Drabek and Stephenson 1971).

Face-to-face or direct personal transmittal is the most effective mode of communicating a warning. The personal contact conveys the urgency of the situation. Sirens, because they are ambiguous, are usually the least effective. Mass media receives mixed reviews; it may be effective in some situations and unheeded in others.

Message content can vary tremendously, and there are no magic formats or words that characterize an effective message. The chief style parameters influencing believability are whether the message is precise, accurate, and consistent and clearly stated in simple language. Features of the message content that relate to believability are the length of time to the disaster impact, the location of the projected impact, the projected certainty of the disaster, and the projected magnitude of the risks. These features of content form a dimension that relates to "fear arousal." Messages should maximize people's definitions of potential danger but should not elicit high levels of fear (Mileti 1975). A critical factor, for example, in the decision to evacuate in response to flood warning is a message that conveys to the listener perceptions of the threats that are real and imminent (Perry, Green, and Lindell 1980).

Previous research has shown that an almost universal human response to an initial warning is to confirm the message. People rarely respond to a single warning without clarification or reinforcement. They want to know what neighbors, friends, or relatives are going to do. They want to be sure they should respond and, if they decide to respond, to do the correct thing. Thus, consistency and accuracy in confirmation are strong determinants of response. Similarly, the frequency or number of times the warning is received shapes its believability.

Several factors external to the warning system are significant. First, the presence of environmental cues (or visual confirmation) is often important. People evacuate floodplains when they see rising water. Second, experience influences behavior. Those people who have been in a similar situation are more responsive to a warning than the uninitiated. Finally, age and socioeconomic status influence response. Elderly people are less likely to hear a warning, believe it when they do hear it, or respond to it after hearing it. Likewise, warnings are usually less effective in reaching and influencing people of low socioeconomic status.

Table 3.1 summarizes these research findings.* The next subsection integrates these observations with other factors that bear on the early warning issue at the Fort St. Vrain facility.

*These can be utilized as criteria to evaluate the effectiveness of a warning system from a behavioral standpoint.

Table 3.1. What makes a warning believable?

Factors determining warning belief	Relationship
Factors internal to the warning system	
Number of warnings	As the number of warnings received increases, the believability also increases
Warning source	Official sources are more believable
Warning channel	Direct personal contact is more believable than impersonal channels
Warning message	Accurate, clear, and consistent messages are more believable
Timing	As the length of time to impact decreases, the believability increases
Location	The closer the recipient is to the impact location, the greater the believability
Certainty	As the likelihood or probability of the event increases, the believability also increases
Risk	As the forecasted consequences become larger, the believability increases
Rumor	As the number of conflicting rumors increases, the believability decreases
Factors external to the warning system	
Socioeconomic status	As socioeconomic status increases, people are more likely to believe
Experience	People who have experienced a disaster are more likely to believe
Environmental cues	If visually or audibly confirmed, the warning is more believable

3.1.3 Improving the warning system

The early warning issue can be potentially resolved by addressing the following questions:

1. If the technical basis for the accident scenarios is correct, does the existing warning system notify people in sufficient time for them to take protective actions or exhibit adaptive behavior?

2. Will existing warning procedures accurately and effectively notify the public?

3. Will the system reach all persons potentially at risk or all who would want to take protective actions?

Prior to addressing these questions, several key points should be noted. First, a warning system will never be perfect, chiefly because the recipients of the warnings will not always hear the same things, despite the fact that they are receiving the same message (Mileti 1975). Second, an appropriate level of effectiveness for a warning system cannot be addressed on technical grounds alone. Essentially, such effectiveness is a subjective question based on values, acceptable risks, and human preferences. Such factors are extremely difficult to assess (Burton and Whyte 1980). Finally, a warning system should be appraised on economic grounds, although this is problematic for the same reasons. Large per capita expenditures may not be viewed favorably in times of inflation and fiscal conservatism.

3.1.3.1 Time

According to accident analyses in the FSAR, there would be a minimum of 20 h before any risks to the public could occur. This provides more than adequate time to disseminate a warning to population at potential risk using existing procedures specified in the state emergency plan, assuming that there are no difficulties in detecting and assessing the accident, that no breakdowns in communications occur, that the decision to warn is efficiently made, and that warnings are disseminated according to plans. Delays can reduce the amount of time available to notify the public.

The length of warning time is similar to that for a major hurricane threatening the Gulf Coast. Lack of time, however, has not been a problem in notifying people of an impending hurricane. Studies have shown, in fact, that many people delay taking adaptive actions such as evacuation until the event is closer in time (Baker 1980).

Should technical evaluations provide evidence that would extend the 20 h, then a greater margin for human error would exist, although this would not warrant a change in warning procedures. If the realistic lead time is revised downward, another assessment should be made of warning system adequacy.

Findings: Based on the 20-h time for notification endorsed by PSC, it would appear that adequate time is allowed to alert the sparse population in the 5-mile (~8-km) EPZ using media and personal communications. As required by NUREG-0654/FEMA-REP-1 (Rev. 1) criteria, a test should be made to assess the length of time it takes to accomplish various levels of notification. Second, an assessment of all possible delays in disseminating a warning should be made. Factors that could contribute to system breakdown should be identified and their likelihoods assessed. The length of each possible delay should also be estimated. A "worst-case" warning scenario could then be utilized to evaluate the maximum length of time needed to warn.

3.1.3.2 Effectiveness

Warning system effectiveness is a complex and subjective topic. The Fort St. Vrain system will be assessed on the basis of the criteria in Table 3.2. Other observations, where appropriate, will be made to assess effectiveness. Manipulatable factors (those that can be changed to improve efficiency) include the following:

Number of warnings. The Fort St. Vrain warning system procedures do not specify how often warnings will be issued or how frequently updated information will be incorporated in the message. It can be assumed that door-to-door notifications will be made only once. How much media coverage will reach individuals is difficult to predict. Hence, frequency of warnings is an unknown factor in evaluating effectiveness.

Table 3.2. Fort St. Vrain warning system effectiveness in light of social science criteria

Factors determining belief	Findings
	Factors internal to the warning system
Number of warnings	No guidelines on frequency of warnings are provided
Warning source	This factor is variable
Channel	Door-to-door is highly effective although prone to contain errors
	Ambiguous sirens are avoided
	Media effectiveness is not known
Message	Official messages need improvement because of ambiguity and confusing contents
Timing	It is more than adequate, although sometimes too much lead time reduces effectiveness
Location	Specificity increases effectiveness
Certainty	Messages appear to be uncertain, reducing effectiveness
Risk	Risks are not clearly outlined, reducing effectiveness
Rumor	This is an unknown entity
	There are no provisions for rumor control in warning procedure
	Factors external to the warning system
Socioeconomic status	This is not estimated in this study
Experience	Lack of incidents will decrease effectiveness, although TMI provides a surrogate
	Public involvement in testing will increase effectiveness
Environmental cues	There may be "false" environmental cues

Table 3.2 (continued)

Factors determining belief	Findings
	Other factors
Public information	Will increase effectiveness
Situational — time of day	Will vary the effectiveness
False alarms	A few will not hurt the effectiveness
Conflicting media reports	Will greatly decrease effectiveness
Sex	Women may be more likely to listen to warning
Confirmation	Depends on individual and mechanism to confirm

Warning channel. The Fort St. Vrain system chiefly relies on door-to-door contact for evacuation notification and on media (TV and radio) as the general channel. The personalized contact will increase effectiveness. The impact of warnings received through the media is not well known (National Academy of Science 1980). The avoidance of siren systems will increase effectiveness of the notification, although it may delay the alert. For example, several studies have shown that sirens are confusing and often misinterpreted; a major cause of fatalities in the 1960 Hilo, Hawaii, tsunami has been considered ambiguity in the interpretation of sirens (Lachman, Tatsuoka, and Bonk 1961).

Warning message. The sample messages (attachment to Appendix A) could create some confusion, because of certain contradictory elements in the messages. For example, the messages first state that there is a reason for public concern in that a release of radioactive materials has taken place. Messages then proceed to denegate that by stating people should not be concerned . . . "there is no cause for alarm" . . . or "no serious hazard." This is a confusing message. Obviously, there is cause for concern, and people will be concerned. They will probably want far more information than is provided in those sample messages. The people will also demand much more precise reasons for being or not being concerned. More detailed instructions should be presented. The failure to do so will likely result in the same type of confusion that was experienced at TMI.

Specification of location. The messages are very precise as to the small areas likely to be affected by a radioactive release. This is desirable. Attention should also be given to specifying more detailed information for other areas as well. Information on safe locations is also valuable. Maps and other graphic means are usually an effective way of communicating the spatial variability of risks to the public.

Certainty. The sample messages tend to convey some uncertainty about what is occurring. This stems from the conflicting depictions of appropriate levels of public concern, from the lack of details, and from the use of conditional phrases such as "may occur," "not expected," or "however." This will decrease effectiveness.

Risk. In a similar manner, risks are not clearly stated in the message, despite the cognitively fearsome statements of radioactive releases. It cannot be assumed that the population has the same knowledge about risks as radiological experts. Second, individuals vary in their willingness to accept or tolerate risks (Slovic 1980). Thus, overresponse and lack of response should be expected to occur because of the lack of ability to interpret risks and different risk-acceptance levels. This suggests that more background information and more details on consequences are needed in the warning message.

Rumor. The extent of rumor in any emergency is difficult to predict. Rumor control is an important part of enhancing warning system effectiveness. A predetermined mechanism for controlling rumor is not integrated into the Fort St. Vrain warning system.

Factors that cannot be manipulated with ease but are determinants of effectiveness include the following:

Socioeconomic status. While no data have been collected on the characteristics of residents of the EPZ, research shows that people in rural areas are less likely to heed warnings than urbanites (Foster 1980). This would create a need for extra effort in warning the rural residents surrounding the Fort St. Vrain site.

Experience. Numerous studies have shown experience to be a major factor in making a warning system work efficiently (Sorensen and Gershmehl 1980). Obviously, there has been little experience with nuclear power plant accidents nationwide and no previous accidents at the Fort St. Vrain plant. To some extent, the TMI incident may educate people about nuclear accidents, thus benefiting the warning process for all power plants. In a more pragmatic sense, test-exercises that involve the public in the warning and response aspects of the emergency may provide simulated experience that increases warning system efficiency.

Environmental cues. There will not necessarily be any environmental cues in a nuclear accident. There may be false cues, such as a plume of steam rising from a cooling tower, which would be, in fact, harmless. In certain instances, smoke from a fire or noise from a rupture of a pressurized container could occur.

Situation. Situational circumstances, such as time of day or season, may have considerable significance for warning system efficiency. It is more difficult to alert people at night than in the daytime. Special provisions for warning during commuter periods may be necessary. In addition, the time of year may pose specific problems. Gruntfest (1977) found that vacationers and campers were difficult for officials to warn prior to a flash flood in the nearby Big Thompson Canyon, Colorado. Problems with transients may exist regardless of the type of warning system utilized.

False alarms. Emergency managers are frequently concerned about the "cry wolf" syndrome. If the warning proves to be a false alarm, people will be less prone to respond to subsequent warnings. Practical experience with natural hazard warnings, such as hurricanes, shows that people are not subject to this phenomenon when false alarms are infrequent. In fact, an occasional false alarm may increase system efficiency, because it serves as an educational device. The precise relationship between false alarms and warning efficiency has not been ascertained.

Conflicting media reports. Any well-designed and integrated warning system can be undermined by the media during an emergency. Conflicting information, sensationalism, and misinterpretations by improper journalistic behavior are significant problems. For example, ridicule of government instructions for protection against volcanic risks detracted from official efforts to educate and warn the public during the early stages of the eruption of Mt. St. Helens volcano (Sorensen 1981b).

Sex. Previous research has shown that women are more concerned about nuclear risks than men (Hohenemser, Kasperson, and Kates 1977). Sex differences also influence warning beliefs and response (Mileti 1975). From these findings, one would postulate that women would be more likely to listen to and respond to a warning regarding a nuclear power plant emergency.

This discussion has highlighted some of the major implications of warnings research for evaluating the effectiveness of current warning procedures at the Fort St. Vrain nuclear reactor. The reader should be cautioned that they are only implications and are not derived from an empirical study of the Fort St. Vrain situation itself. Nevertheless, this review points out several ways in which the warning system can be improved and its general level of effectiveness can be enhanced.

Findings. The Fort St. Vrain warning procedures have no serious deficiencies in effectiveness when evaluated in light of generalized research findings. Improvements in the existing system could be made without major investments of time and money.

3.1.3.3 Coverage

It is difficult to determine the extent or the comprehensiveness of the warning system coverage. Using PSC data, it is estimated that about 3400 people reside within a 5-mile (~8-km) radius of the plant, with an additional 9700 in the 5- to 10-mile (∿8- to 16-km) band. Assuming an average household size of 3.25 persons, this roughly translates into 1050 and 3000 families in the two emergency zones. At some times during the day, media could reach a fairly large number of families. During normal sleeping hours, a greater reliance on personal contact would be necessary. Door-to-door notification would take longer at night.

Personal notification may not reach 100% of the population, because of several factors. First, people may be inaccessible. This will be the case particularly in farming households or if a person's place of employment is outside the EPZ. Second, it is possible that officials carrying out the notification would overlook some households. Finally, people may not comprehend or may misinterpret the warning message. Further work is needed to gain a clearer understanding of warning coverage.

3.1.3.4 Specificity of instructions to warning officials

Appendix A contains the procedures that instruct warning officials to issue public warnings about a radiological emergency at Fort St. Vrain. While they provide an adequate description of general processes and an overview of the general approach utilized to issue a warning, they lack details for easy or perhaps effective implementation.

Of course, emergency officials often assume that details are unnecessary, because they already know how to implement general guidelines. Changes in personnel or new procedures can invalidate this assumption. It is, therefore, desirable to have plans with sufficient detail to enable implementation without assuming possession of background knowledge.

It would also be desirable to provide greater details about warnings in the emergency plan that would be more reflective of what actually needs to be done should a warning be issued.

3.1.4 Implications

The NRC/FEMA criteria for early warning systems should be reassessed for the HTGR technology and reevaluated for all reactors in light of nontechnical considerations, such as the behavioral science factors discussed in this report.

This preliminary appraisal of the Fort St. Vrain warning system revealed no major problems. It is likely that the system would adequately perform its function if put to a real test. Small improvements would likely increase its effectiveness. Further assessments of warning lead times derived from accident scenario analyses are needed. Periodic assessment of the warning system through testing and an examination of possible constraints on warning dissemination should be conducted by an independent party. Further examination of coverage is needed. More detailed specification of warning procedures should be given attention.

3.2 WARNING RESPONSIBILITY

A question related to early warning capability concerns the locus of responsibility for the development of the warning system. The criteria state that it is the licensee's responsibility to demonstrate that criteria are met. PSC's position is that all responsibilities for warning should be placed within the state government. DODES agrees with this position. This leads to several conclusions.

1. If the state's assumption of full responsibility for the warning system is allowed, then the burden of developing an early warning capability is theirs.

2. If the early warning issue is resolved, the burden of responsibility becomes a moot issue, because PSC has already demonstrated that the system exists.

3.2.1 Previous research

No previous research appears relevant to this issue, since the distinction between demonstrating the ability to implement and actual implementation of the warning system is not particularly important from a behavioral perspective.

3.2.2 Implications

Conversely, this issue raises interesting legal considerations. If the state assumes responsibility for all warning-related affairs, can the state be forced to conform to NRC/FEMA criteria through litigation? Second, what authority does NRC/FEMA have over state radiological planning? Third, if an accident occurs and warnings are indadequate, who is liable for damages resulting from the failure to warn?

Findings. A thorough legal review of this issue is required to help resolve the questions stated previously and other potential problems.

3.3 PUBLIC INFORMATION AND EDUCATION*

A general theme in the management of risks and hazard is that the public should be made aware of the nature and consequences of the potential threats and of what to do if an emergency occurs. It is assumed that with greater levels of knowledge, people will be better able to respond adaptively to a warning of a potential disaster when confronted with a threatening situation (Sorensen 1981a; White and Haas 1975). It is assumed that a similar rationale is the basis for the NRC/FEMA criteria on public information for support of radiological emergency preparedness plans.

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*Much of this section is derived from a previous study by the author; see Sorensen (1981a).

3.3.1 Behavioral considerations on information and education

3.3.1.1 Concepts

The study of hazard education or information dissemination is somewhat hampered by the vague and often ambiguous nature of the terms. These terms may mean something quite different to a local civil defense director than to a city planner or grade school teacher. This problem is not limited to issues concerning nuclear power management but pervades other environmental problems, including energy conservation, natural hazards, and other issues with both scientific and behavioral components. The confusion arises, it is suspected, because "education" covers a wide range of activities, includes a diverse number of topics, involves a multitude of "teachers," and is aimed at a variety of "students." Education can be defined as activities that inform people on how to prepare for and respond to a potentially damaging accident.

Given this definition, education appears to be closely related to the process of communication defined in diffusion of innovation models (Rogers and Shoemaker 1971) or in theories of attitude formation and change (Fishbein and Ajzen 1975). The basic notion is that a message (information) emanates from a source, proceeds through a channel (education or information dissemination), and reaches the receiver. The message can effect a change in levels of knowledge, in attitudes, and in behavior. This paradigm, taken alone, however, has not proved adequate in understanding hazard-related communication processes (Mileti et al. 1979).

3.3.1.2 Findings from previous research

Geographic studies on natural hazards offer a model of human behavior that implicitly relates educational processes to dispositions, behavioral intents, and decisions about adopting measures to mitigate hazard consequences (Burton, Kates, and White 1978). Sociological studies of natural hazard warnings and their effects lend further insight into the questions raised about hazard education (Mileti 1975). A review of this body of literature allows some relevant observations.

Levels of formal education, in general, have not been significant in explaining various dimensions of human perception and response to a wide range of geophysical hazards (Burton, Kates, and White 1978). For example, in a carefully designed study of earthquake and flood insurance, it was found that educational levels were not related to the insurance purchase decision (Kunreuther 1978). Baker (1979), in a review of studies on response to hurricane warnings, found that educational level was significant in explaining evacuation behavior in only one of four studies. Furthermore, educational levels are not related to the ability to understand or comprehend hazard-warning messages (Mileti 1975).

Special information dissemination programs have not been highly effective in changing people's perceptions or behaviors. Roder (1961) discovered that providing flood-hazard maps to residents of Topeka, Kansas, floodplains did not result in any measurable impacts. A longitudinal study of a hazard education program in Crescent City, California, following a tsunami in 1964 revealed that the education did not enhance adaptive response to a later warning (Haas and Trainer 1973). Waterstone (1978) showed that the distribution of a flood-hazard brochure to residents of floodplains in the Denver area heightened hazard awareness, but that it was not nearly as important as experience in promoting hazard-mitigating behavior.

More recently, Baker (1980) questioned whether information and awareness campaigns lead to greater levels of evacuation in response to a hurricane warning. He concluded that blanket approaches are only marginally effective, while individualized approaches containing specific risk information are more desirable.

Thus, previous research is inconclusive as to whether information programs are beneficial in enhancing response or promoting adaptive behavior in response to a warning.

3.3.2 Implications

The results cited indicate that the usefulness of any specific information program is largely unknown. Because the generalizability of previous studies to this specific situation is questionable, the nature of the impacts from educational programs at the Fort St. Vrain facility is unclear.

Findings. Because of this uncertainty, it is recommended that a survey of the public concerning their ability to hear the warning and their knowledge about the availability of information, as required by NUREG-0654/FEMA-REP-1 (Rev. 1), should be used to evaluate the effectiveness of the brochure. This should be done independently of PSC, Fort St. Vrain, or DODES to ensure objectivity. Properly designed, this study would be useful in answering questions about the effectiveness of nuclear-related information programs.

4. LEARNING FROM TMI: IMPLICATIONS FOR EMERGENCY PLANNING

The accident at TMI provided a unique opportunity to observe and study public response to an actual emergency. The ensuing studies can be helpful in evaluating the Fort St. Vrain warning plan. To date, at least seven major surveys of public attitudes and behavior in relationship to TMI have been made (Flynn 1981). Several reviews, summaries, and critiques of these studies have been attempted (Flynn 1981, Dynes et al 1979, Mileti 1981, Dohrenwend et al. 1981). Together with a number of non-empirical studies, reviews, and opinion papers that have been published since the incident, these studies provide an important set of lessons for radiological preparedness planning (Fisher 1981, Olds 1981b, Hull 1981b, Marrett 1981). Some of these lessons have resulted in policy changes and new planning criteria. Others have been overlooked or have not been incorporated into guidelines or regulations. Several criticisms have been leveled at changes in emergency planning brought about by TMI (Hull 1981a, Olds 1981a). The following discussion reviews the social science findings from TMI studies that bear on emergency planning at Fort St. Vrain.

4.1 FINDINGS AT THE INDIVIDUAL AND FAMILY LEVELS

The following key research findings, summarized in point form, have been drawn from the studies cited. They represent a consensus of findings and are not necessarily specific to any single study.

1. Individuals felt that they lacked information on the accident situation and what to do about the situation.

2. Individuals were receiving conflicting information and rumors that lacked validity. This created confusion regarding appropriate actions to take.

3. Individuals lacked the knowledge to understand the consequences or implications of information they were receiving. This created uncertainty over such critical topics as negative health effects.

4. The situation was slow in developing; thus, people had several days to form images of what was happening and to make decisions about appropriate responses.

5. Evacuation decisions were an individual or family choice, as no official evacuation notice was issued. The statement made by the governor on evacuation of pregnant women and small children was only an advisory and never an official order.

6. An estimated 55 to 62% of the population within a 5-mile (∿8-km) radius evacuated. An estimated 44 to 54% of the population 5 to 10 miles (∿8 to 16 km) away also evacuated.

7. Evacuation levels declined with distance from the TMI site.

8. Women were more likely to evacuate than men. Pregnant women were almost certain to leave.

9. Major reasons for staying (not evacuating) were
   a) could not leave job;
   b) waiting for an official order;
   c) it was in God's hands; and
   d) there was no danger.

10. People were stressed by the situation and affected by other psychological impacts. The precise magnitudes and implications of these effects are difficult to establish.

11. The incident increased individuals' distrust of the nuclear industry and increased negative attitudes toward nuclear power development.

4.2 FINDINGS AT THE EMERGENCY MANAGEMENT LEVEL

Numerous agencies and organizations played roles in the emergency-response effort at TMI. In addition to the licensee, ten federal agencies/organizations, eight state agencies/organizations, five county civil defense groups, and numerous local government departments and groups participated in managing the crisis (Dynes et al. 1979). Postaccident assessments identified the following lessons:

1. There was a distinct lack of planning and emergency preparedness for the accident.

2. A partial result of the lack of planning was a lack of coordination among the myriad of emergency managers.

3. Part of the lack of coordination was due to the lack of communications among key personnel.

4. Lack of coordination can also be attributed to the lack of information. Specifically, information was deficient because:
   a. some did not exist;
   b. some did exist but was not available;
   c. some could not be understood or interpreted.

5. As a result, there was a great deal of uncertainty about how to respond.

6. The uncertainty and confusion was conveyed to the public as part of the warning.

7. The warning system subsequently "broke down," because it lacked authority and contained contradictions.

4.3 IMPLICATIONS

4.3.1 General

The following conclusions can be drawn from the TMI experience:

1. Some people are risk-adverse to nuclear power. If informed of imminent danger, some will evacuate or take precautionary action regardless of whether it is officially recommended.

2. Many people tend to view nuclear power with both dread and uncertainty (Fischhoff et al. 1981). Thus, many people will respond in a manner that prevents cognitive dissonance: nuclear accidents are dangerous; I live nearby; I don't want to be exposed to radiation; therefore, I will leave. This cognitive process will work to promote evacuation despite official recommendations.

3. All people, the public as well as experts, will be confronted by uncertainty in a radiological emergency. This makes decisions more difficult and time-consuming, which could be a delaying factor in evacuations.

4. Because of inherent complexities of the technology and public inexperience with accidents, the ability to issue warnings that reflect appropriate risks and determine appropriate levels of public concern and response is probably unachievable. The TMI

experience, however, pointed out a number of actions to avoid in the warning process.

5. Despite what officials say, people will likely continue to hear a variety of different messages, because of situational factors and errors and biases in information processing.

6. There is not a "perfect" warning system by which to judge the effectiveness of a single warning experience such as TMI. Improvement of warning and emergency planning is an incremental process based on applying research findings and experience gained from previous emergencies and exercises.

4.3.2 Implications for Fort St. Vrain emergency planning

Although the Fort St. Vrain power reactor may never have an accident that requires evacuation or other protective actions in a technical sense, any anomalous event that results in a public notification puts the warning/response mechanism in gear. People may react in a manner that is consistent with their internal beliefs but not necessarily consistent with the beliefs of emergency managers or technical experts. Thus, regardless of the warning message contents, decisions concerning evacuation and other protective actions are ultimately individual ones. This must be recognized both in the formal planning efforts and in the design of a warning system.

The processes of warning and emergency planning are highly dependent on preaccident activities that involve or reach the public. Strong evidence suggests that emergency preparations should be made in an open and candid fashion. This helps to minimize the secretive atmosphere that has worked against favorable public perceptions of complex technological systems in the past. Public information, the demonstration of safety capabilities, and the expression of preparedness through periodic tests should be desirable from a public relations as well as an emergency-planning perspective.

People need to know what an "accident" is and how to respond and interpret information. These are important goals of public information programs. It is not clear, however, how well information programs are preparing people for responding to a radiological emergency.

Thus, before an emergency and when an emergency does occur, people need accurate and concise information from one official source. Conflicting information will undermine credibility and hamper long-run emergency-planning efforts.

The bottom line from the TMI experience is that a little emergency planning that incorporates the public into the planning process before it is needed can be very helpful in an emergency and perhaps beneficial as an educational experience even if an accident never occurs.

4.3.3 Findings

A review of social science research findings on TMI reinforces the conclusions and recommendations in the previous section. Specific conclusions include the following:

1. A 15-min alert capability may not be a critical factor in determining the amount of time it takes for the population to evacuate.

2. A warning system should be designed to meet the characteristics and needs of the population residing in the EPZ.

3. A warning system should be based on the best possible understanding of the technical basis of emergencies and potential consequences.

4. Cooperation between licensees, the state, local governments, and others involved in emergency operations is extremely vital to achieve effective response.

5. Public information is important, although how it affects public response is not well understood.

5. SUMMARY AND CONCLUSIONS

This report addresses three issues concerning the applicability of the TMI action plan to the Fort St. Vrain HTGR power plant. The issues are these:

1. meeting early warning criteria,

2. responsibility for warning system demonstration, and

3. adequacy of public information program.

These issues were analyzed in light of current knowledge on hazard warning systems and in light of the TMI incident. The major conclusions arrived at include the following:

1. Warnings

   a. NRC/FEMA warning system criteria are not fully applicable to the Fort St. Vrain operation, because of the difference in warning lead time between HTGRs and LWRs. Further technical analysis should be made to define the most likely lead time and the minimum lead time for various accident scenarios. NRC/FEMA should then specify new warning criteria for HTGR technology.

b. In view of this analysis, the original Fort St. Vrain warning system appears to have been adequate to warn the public in the event of an emergency; however, further improvements could be made. These include developing more specific procedures, improving warning messages, establishing a rumor-control mechanism, and developing better risk information and graphic displays. While the tone-alert radio additions likely improved the system, it is not clear whether they were indeed necessary.

c. Further empirical studies on problems and constraints in operating the warning system should be made to validate findings derived from applying general concepts and principles from previous research. This could be done in conjunction with an emergency exercise.

2. Responsibility

a. Who is responsible for demonstrating the warning system is not a significant issue, because the implementation of the system is far more critical in determining warning system effectiveness. Coordination among the licensee and government groups in demonstrating the system should be of high priority.

b. A legal analysis of this issue to assess liability for the warning system operations would be prudent.

3. Public information

a. PSC has complied with NRC/FEMA requirements for public information. The impact of PSC's program on the preparedness capabilities of the public is, however, unknown.

b. There is no evidence that PSC has conducted a survey to determine the coverage of the warning system and the public information program. Further work should be done to independently evaluate the effectiveness of the public information efforts as they apply to emergency preparedness and response.

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APPENDIX A

WARNING PROCEDURES

FORT ST. VRAIN NUCLEAR POWER PLANT

Source:

DODES Radiological
Emergency Response
Plan

COLORADO
RADIOLOGICAL EMERGENCY RESPONSE PLAN
FORT ST. VRAIN

Annex C - Warning

I PURPOSE

To provide a coordinated method of disseminating warnings to the populace in the event of an incident at the Fort St. Vrain facility.

II CONCEPT OF OPERATIONS

A. The Colorado Department of Health, based on their assessment of the incident, will determine when warnings should be issued to the populace and the content of the warning messages.

B. The Colorado Department of Health will notify the Weld County Sheriff and the State Division of Disaster Emergency Services of their decision and the content of the warning messages.

C. The Colorado Department of Health will then request those commercial broadcast stations listed in Attachment 1 to issue the warning to the public.

D. The State Division of Disaster Emergency Services will notify the Governor of the action being taken.

E. The Weld County Sheriff will disseminate the warning by whatever means are appropriate and available to include:

1. Sounding the Civil Defense warning sirens in the affected area, if available.

2. Having loudspeaker equipped vehicles announce the warning in the affected area.

3. Utilizing the telephone to alert or warn school authorities and other densely populated facilities or institutions in the affected area.

4. Door-to-door notification where practical or possible.

5. Requesting NOAA Weather Radio to broadcast warning messages.

F. Warning messages will contain: (See Attachment 2)

1. A brief statement of the situation.

2. A geographical description of the area affected.

3. Citizens actions to be taken, to include tuning their radio and television sets to specific stations.

4. Additional information, as appropriate.

III RESPONSIBILITIES

A. Colorado Department of Health is responsible for:

1. Determining when warnings should be issued.

2. Determining content of warning messages.

3. Notifying the Weld County Sheriff of the warnings and their content and affirming he will follow correct emergency actions.

4. Notifying the commercial broadcast stations.

5. Notifying the State Division of Disaster Emergency Services.

6. Correcting any known inaccuracies in a broadcast warning.

7. Notifying the news media of the actions being taken.

B. Colorado Division of Disaster Emergency Services is responsible for:

1. Notifying the Governor of the warnings being issued.

2. Notifying the Emergency Broadcast System (EBS) radio and television stations of the appropriate warning messages to be broadcast.

C. Weld County Sheriff is responsible for:

1. Coordinating with the Weld County Civil Defense Coordinator, to have the Civil Defense sirens sounded in the affected area, if available.

2. Dispatching loudspeaker equipped vehicles into the affected area to disseminate the warning messages.

3. Coordinating with the Weld County Civil Defense Coordinator, the use of the telephone and citizen band radio system to relay warning messages to schools and other facilities or institutions, or isolated farm families.

4. Dispatching personnel for door-to-door notification, especially to known handicapped or infirm persons.

D. Public Service Company is responsible for:

1. Warning plant employees, visitors and tenants on site property.

2. Alerting the Colorado Department of Health to correct any known inaccuracies in a broadcast warning.

E. Weld County Civil Defense Coordinator is responsible for:

1. Activating the local Emergency Broadcast System (EBS) to relay warning over those stations participating in the Emergency Broadcast System.

ATTACHMENT 1

AREA COMMERCIAL BROADCAST STATIONS FOR WARNING DISSEMINATION

TELEVISION STATIONS

			TELEPHONE
KOA	Denver	Channel 4	861-4444/ 830-6464
KMGH	Denver	Channel 7	832-7777/ 832-0177
KBTV	Denver	Channel 9	825-5288/ 893-4491/4499
KWGN	Denver	Channel 2	832-2222/ 837-1561
KYCU	Cheyenne	Channel 5	(307)634-7755

RADIO STATIONS

		FREQUENCY AM	FREQUENCY FM	TELEPHONE
KOA (EBS Station)	Denver	850		861-4444/ 830-6464
KFKA	Greeley	1310		356-1310
KYOU	Greeley	1450		356-1450
KFKZ	Greeley		99.1	623-1310
KGRE	Greeley		96.1	356-1452
KUNC	Greeley		92.3	351-2915
KRNK	Greeley		91.5	351-6397
KUAD	Windsor	1170		686-2791

ATTACHMENT 2

SAMPLE WARNING MESSAGES

1. INFORMATIONAL MESSAGE IN CASE OF A RADIOLOGICAL ALERT

THE COLORADO DEPARTMENT OF HEALTH REPORTS THAT AN INCIDENT INVOLVING THE POSSIBLE RELEASE OF RADIOACTIVE MATERIAL IN THE ATMOSPHERE OCCURRED AT THE FORT ST. VRAIN NUCLEAR GENERATING PLANT AT ________(time). THE EXACT SCOPE OF THE INCIDENT IS NOT KNOWN AT THIS TIME. IT IS KNOWN THERE IS NO CAUSE FOR ALARM. WE ASK THAT YOU STAY TUNED TO ________(station) SO THAT WE MAY KEEP YOU INFORMED. WE REPEAT THERE IS NO CAUSE FOR ALARM. RADIATION RESPONSE SPECIALISTS ARE (ON THE WAY TO THE SITE) (ON THE SCENE) TO ASSESS THE SITUATION. THIS STATION WILL KEEP YOU ADVISED AS MORE INFORMATION BECOMES AVAILABLE.

2. PROTECTIVE MEASURES MESSAGE IN CASE OF A RADIOLOGICAL EMERGENCY

THE COLORADO DEPARTMENT OF HEALTH REPORTS THAT AN INCIDENT INVOLVING THE ACCIDENTAL RELEASE OF RADIOACTIVE MATERIAL IN THE ATMOSPHERE OCCURRED AT THE FORT ST. VRAIN NUCLEAR GENERATING PLANT AT ________(time). THE AMOUNT OF RADIOACTIVITY RELEASED IS NOT EXPECTED TO CONSTITUTE A SERIOUS HEALTH HAZARD. THERE IS NO CAUSE FOR ALARM. HOWEVER, AS A PRECAUTIONARY MEASURE, THOSE RESIDENTS LIVING IN AN AREA BOUNDED BY ________________ (road identifications) SHOULD REMAIN IN THEIR HOMES AND TAKE THE FOLLOWING ADDITIONAL PROTECTIVE MEASURES:________________

____.

RESIDENTS OF OTHER AREAS SHOULD REMAIN OUT OF THIS AREA, BUT

OTHERWISE NEED TO TAKE NO PROTECTIVE MEASURES AT THIS TIME. RADIATION RESPONSE SPECIALISTS ARE ON THE SCENE. THIS STATION WILL KEEP YOU ADVISED AS MORE INFORMATION BECOMES AVAILABLE.

3. EVACUATION ORDER MESSAGE IN CONNECTION WITH A RADIOLOGICAL EMERGENCY

THE COLORADO DEPARTMENT OF HEALTH REPORTS THAT AN ACCIDENTAL RELEASE OF RADIOACTIVE MATERIAL IN THE ATMOSPHERE OCCURRED AT THE FORT ST. VRAIN NUCLEAR GENERATING PLANT AT APPROXIMATELY _________(Time). THIS INCIDENT IS NOT EXPECTED TO POSE A SERIOUS HEALTH HAZARD TO THE AREA AT LARGE AROUND THE PLANT. HOWEVER, COLORADO DEPARTMENT OF HEALTH OFFICIALS INDICATE THAT UNACCEPTABLE LEVELS OF RADIATION MAY OCCUR IN AN AREA BOUNDED BY ____________________ (road identification) INCLUDING THE COMMUNITY OF _______________. AS A PRECAUTIONARY MEASURE, THE GOVERNOR OF COLORADO HAS DIRECTED THAT THE POPULATION WITHIN THIS AREA AND THE COMMUNITY OF ________ ________________ BE TEMPORARILY EVACUATED. IF YOU LIVE IN THIS AREA, USE YOUR OWN CAR OR OTHER VEHICLE AND PROCEED TO ___________ ______(Greeley or Fort Lupton) AND REPORT IN AT __________________ (Reception Center). IF YOU NEED TRANSPORTATION, CALL THE WELD COUNTY SHERIFF'S DEPARTMENT AT 356-4000, EXTENSION 486. IN LEAVING THE AREA, USE ROUTES ___________________. A TRAFFIC CONTROL POINT AND A RADIOLOGICAL MONITORING TEAM HAVE BEEN SET UP AT THE INTERSECTION OF __________________________(road designations) TO CHECK YOU AND YOUR VEHICLE FOR THE REMOTE POSSIBILITY OF CONTAMINATION AND TO GIVE YOU FURTHER INSTRUCTIONS. BE SURE TO TAKE BEDDING MATERIAL, AN EXTRA SET OF CLOTHES AND ANY SPECIAL PRESCRIPTION MEDICINES WITH YOU. THERE IS NO CAUSE FOR ALARM SO

DRIVE SLOWLY AND SAFELY. THIS IS ONLY A PRECAUTIONARY MEASURE. RADIATION RESPONSE SPECIALISTS ARE MONITORING THE SITUATION CAREFULLY. FURTHER INFORMATION WILL BE PROVIDED BY THIS STATION AS IT BECOMES AVAILABLE.

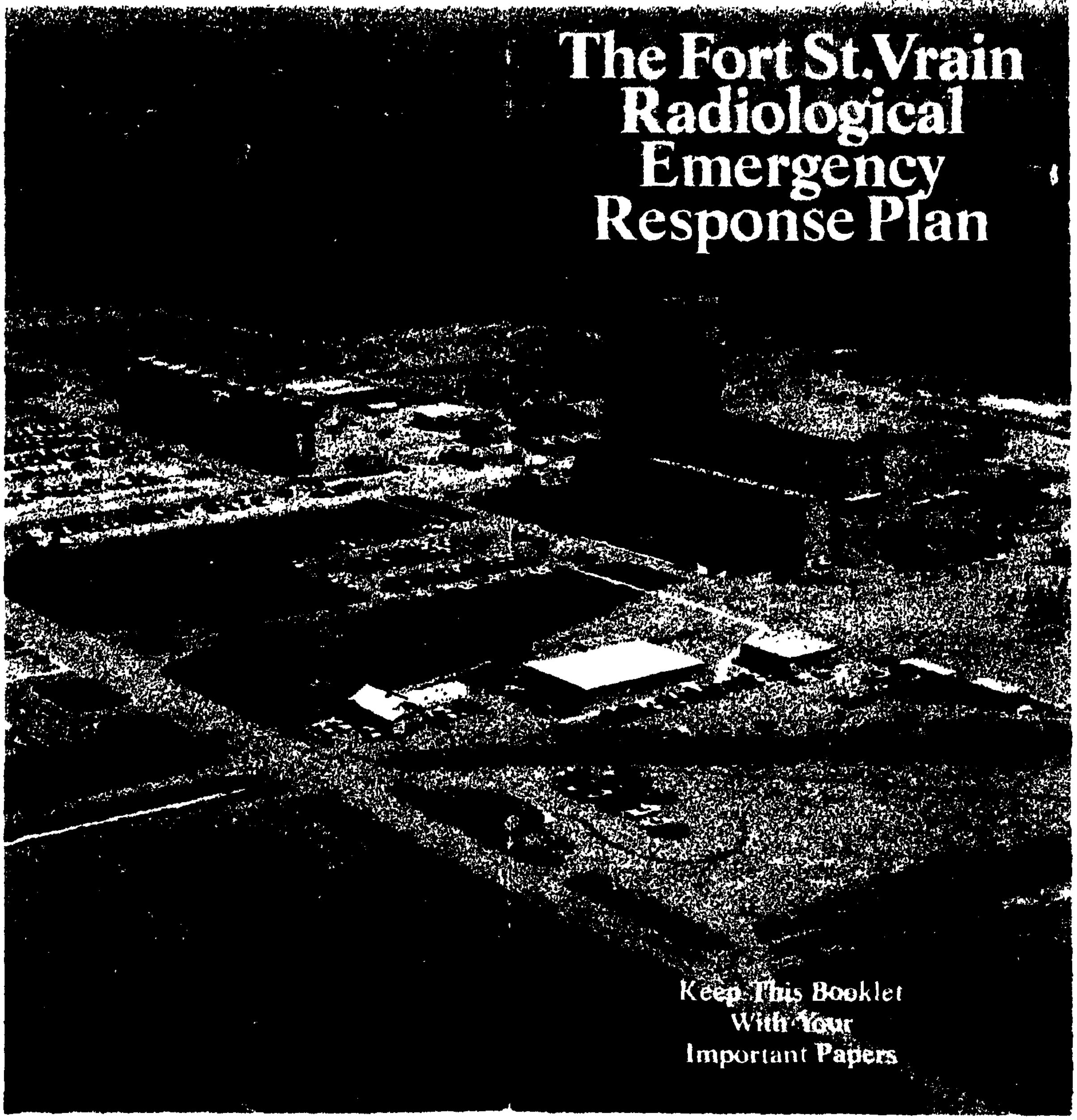
APPENDIX B

PUBLIC BROCHURE

INFORMATION ABOUT THE FORT ST. VRAIN RADIOLOGICAL EMERGENCY RESPONSE PLAN

Source:

Public Service of Colorado


The Fort St. Vrain
Radiological
Emergency
Response Plan
Keep This Booklet
With Your
Important Papers

About This Brochure

Dear Resident:

This brochure is part of an extensive, on-going program by the State of Colorado, Weld County and the Public Service Company to ensure the safety of persons living near the Fort St. Vrain Nuclear Generating Plant. The actual danger posed by the Plant is very small. However, since radioactive materials are involved in the production of electricity at Fort St. Vrain, a Radiological Emergency Response Plan (RERP) has been developed to provide area residents with maximum protection in the case of a radiological accident. This brochure gives information on Fort St. Vrain and the Radiological Emergency Response Plan.

I ask you to read this brochure now and then keep it with your other important papers for future reference.

Sincerely,

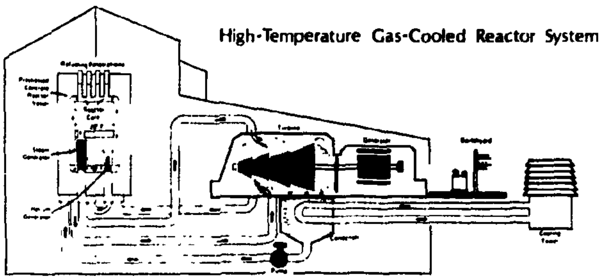
Richard D. Lamm
Governor
State of Colorado

The Fort St. Vrain Nuclear Generating Plant

The Fort St. Vrain Plant is operated by the Public Service Co. of Colorado and is located approximately 37 miles north of downtown Denver and about 3½ miles northwest of Platteville.

Fort St. Vrain is one of the most modern and most efficient nuclear electric generating plants in the United States. It employs a high-temperature, gas-cooled reactor contained in a pre-stressed concrete vessel. Main features of Fort St. Vrain include the use of helium gas as a coolant, use of graphite fuel elements and the use of thorium in conjunction with uranium as a fuel. Helium is a desirable coolant because it is chemically inert, that is, it will not react with other elements in the reactor such as the graphite fuel elements, helium circulators and other components. Also helium is not toxic, nor does it present a fire or explosion hazard. Radioactive material in the plant is used only for the production of electricity.

The Fort St. Vrain reactor is totally different from all other U.S. reactors. The reactor's core is made of graphite and because graphite becomes stronger with increasing temperature, a meltdown is impossible.



High-Temperature Gas-Cooled Reactor System

What is the Risk?

Extensive safety precautions taken at Fort St. Vrain make the hazardous release of radioactive material extremely remote. However, such a possibility must be considered.

There is the remote possibility that the power plant's safety systems could fail, and the primary coolant (helium) could be released into the atmosphere. However, the primary coolant would be rapidly dispersed into the air, and any concentration of radioactivity at ground level would be minimal.

Even if the maximum amount of radioactive material were to be released by an unforseen occurrence at the plant, health and safety experts state that radiological exposure of persons living near the plant would be minimal and even non-existent, depending upon the wind direction.

Protective action as outlined below would greatly minimize any possible exposure to radiation that might occur.

Radiological Emergency Response Plans

Radiological Emergency Response Plans have been developed and exercised by Federal, State and local governments, Public Service Company and volunteer civilian agencies. These Plans are designed to ensure a coordinated response to any emergency that might occur at the Fort St. Vrain nuclear generating station. The plans define responsibilities and prescribe specific actions to be taken to provide for the maximum safety of the general public off the site of the Fort St. Vrain Plant.

How are Incidents Classified?

Should an incident occur at Fort St. Vrain, there are four incident classifications you might hear discussed on the radio or TV or read in the newspapers. So that you will understand their meaning, the are explained in the order of their potential seriousness:

1. Unusual Event — A minor event (normally non-radiological) that affects only the area of the plant and can be handled by Public Service Company. The Nuclear Regulatory Commission (NRC) and certain State and local agencies are notified as a matter of information.

2. Alert — Still a minor event, but a minute quantity of radioactive material is being or potentially could be released off of the reactor site. Federal, State and local officials are notified. Depending upon the situation, the Radiological Emergency Response Plan may be implemented as a precautionary measure in case the situation should become more serious.

3. Site Emergency — A more serious situation has occured at the reactor site. A significant quantity of radioactive material is being or potentially could be released off of the reactor site which could affect people downwind from the plant. Federal, State and local officials, as well as the general public, are notified of the occurance and advised of the protective actions to take. All emergency response forces, including radiological specialists, are activated and the entire Emergency Response Plan is put into action.

4. General Emergency — This is the most serious type of emergency that can occur at a nuclear generating station. Because of its design features, the occurrence of this type of emergency at Fort St. Vrain is so remote as to be virtually impossible. However, emergency plans are ready just in case. All emergency forces know what actions to take, and, of course, the general public will be kept informed of the protective actions to take for their safety.

What Kind of Information Will I Receive?

Public health and safety officials will determine what kind of protective action, if any, is needed. Only persons living within 5 miles of Fort St. Vrain could be affected by a radiological accident. In case of such occurence, you will be advised, and may be directed, to take "In-Place" protection by staying indoors or, perhaps, to evacuate to a designated evacuation center.

What is In-Place Protection?

If you are advised to take "In-Place Protection," you should:

1. Go or remain indoors until further notice.
2. Shut all doors and windows.
3. Turn off air-circulation systems.
4. Listen to radio or television for further information.

If I am Told to Evacuate?

If you are within 5 miles of the Fort St. Vrain Plant, there is a remote possibility that you may be required to evacuate the area. If this happens, here is what you should do:

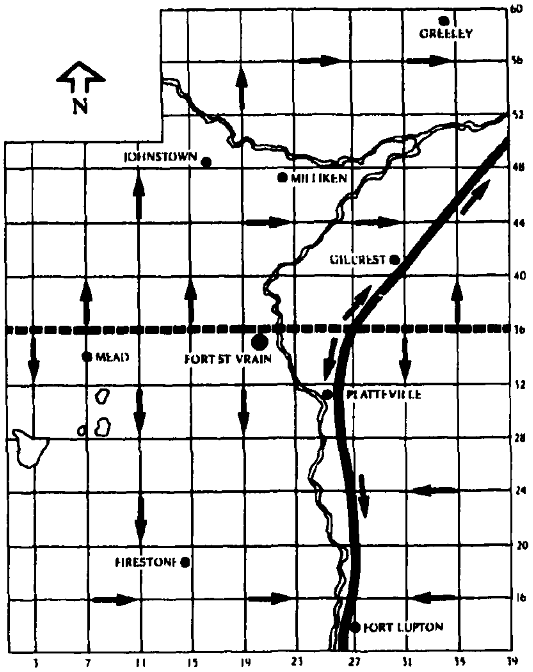
1. Act immediately to evacuate.
2. Put on a dust mask or breath through a damp handkerchief to filter out any dust in the air.
3. If you have been outdoors, change clothing and discard outside your home the clothes you took off.
4. Gather up a change of clothing, personal toilet articles, blankets for each member of your family, special baby formulas, and any special medications you or your family may need at the evacuation center.
5. Check your house to see that all water faucets, lights and appliances are turned off and the windows are closed and locked.
6. As you leave home to evacuate, lock all doors and tie a white handkerchief or piece of white cloth on your mail box or door-knob, so the Sheriff will know you have evacuated.
7. Get into your car or other vehicle, close your car windows and vents and drive slowly and safely to your evacuation center described later in this brochure.
8. If you have room, take additional passengers who have no means of transportation.
9. If you live in the area being evacuated and have no transportation, stay inside your home, and be sure to close all doors, windows and air vents. If you completed and mailed the attached form, wait in your home and someone will come to evacuate you. If you have not sent in the form, call the Weld County Communications Center in Greeley telephone 356-4000 or 911, or the Fort Lupton Police Department telephone 857-6610. A radio dispatched vehicle will pick you up.
10. Continue to listen to emergency broadcasts for any specific instructions that may be announced.
11. Household pets (except guide-dogs) will not be permitted in public shelters. Leave pets at home with a supply of food and water. If a pet must be taken, the Humane Society will provide a temporary animal shelter at your evacuation destination.

Where Do I Go When Told to Evacuate?

The map in this booklet provides several items of information:

1. Various county roads in the vicinity of Fort St. Vrain are identified by a number shown on the bottom and right side of the map.
2. The location of the Fort St. Vrain Plant and all major communities in the area are shown.
3. County Road 36 is identified on the map by a broad, dark line running east and west across the map.
4. If you are told to evacuate and you live north of County Road 36, plan to proceed north to Greeley for temporary lodging. If you live south of County Road 36 and are told to evacuate, plan to go south to Fort Lupton for temporary lodging. However, if for some reason law enforcement personnel direct you otherwise, follow their instructions.
5. The arrows on the map indicate the routes you should follow if you are ordered to evacuate. Locate where you live, and then follow the arrows which guide you to the main evacuation route for your area. Follow all traffic control measures, signs and instructions from law enforcement personnel along the way.
6. All evacuation traffic will be routed through established Traffic Control Points where you will be registered and possibly monitored by trained personnel using Geiger-type instruments to ensure that neither you nor your vehicle has received any significant radioactive contamination.
7. Those proceeding to Greeley for temporary lodging, should report to Greeley Central High School at 1515 14th Avenue for further registration and assignment to a lodging and feeding facility.

Recommended Traffic Flow



7 — County Road Designations

←→ — Evacuee Traffic Rounting

How Will I be Informed?

The public will be alerted and receive instructions by several means.

1. Radio and television broadcasts.
2. Civil Defense sirens will sound a steady tone which means to turn on your radio or television set to a local station.
3. Public safety vehicles, including aircraft, equipped with loudspeakers will tour the affected area making announcements.
4. Door to door messengers will be used where necessary.
5. Weld County officials will alert schools and other facilities by telephone.
6. NOAA Weather Radio will be requested to broadcast aleart messages.

What if No Transportation is Available?

Call: Weld County Communications Center 356-4000 or 911 or Fort Lupton Police Department 857-6610. They will radio dispatch a vehicle to pick you up.

What About the Handicapped, Hard of Hearing or Visually Impaired?

1. If you are handicapped and require assistance to move, or if you have a hearing problem which would make you unable to hear instructions on the radio or from the loudspeakers on the safety vehicles or aircraft, fill out the attached card, tear off, place a 15¢ stamp on it and mail to the:
   Weld County Sheriff
   Post Office Box 759
   Greeley, Colorado 80632
2. If you are a reader for the visually impaired, please assist the person for whom you read and handle mail in filling out the attached form and mailing it to the Weld County Sheriff at the address shown above.
3. If you know of any handicapped persons who live within 5 miles of Fort St. Vrain, please help them to fill out and mail the attached form.

Information in Time of Emergency

In the event of an actual emergency, the telephone lines are likely to be tied up with emergency calls. Your best source of immediate information probably will be the Emergency Broadcast System radio stations. These stations are KOA at 850 or KFKA at 1310 on your AM radio dial.

For Further Information Now

If you have questions concerning any of the information presented in this brochure, you may call:

1. For information on health effects and protective action: Colorado Department of Health 320-8333, Ext. 6246.
2. For specific information on the Radiological Emergency Response Plan: Colorado Division of Disaster Emergency Services 279-2511.

Fort St. Vrain Radiological Emergency Response Plan Glossary of Nuclear Terms

Alpha Particles
Positively charged particles emitted in radioactive decay and nuclear fission. Helium nuclei or alpha rays. (See Radioactivity.)

Background Radiation
Radiation arising from natural radioactive materials always present in the environment, including solar and cosmic radiation and radioactive materials in the upper atmosphere, the ground, building materials and the human body. (See Radioactivity.)

Beta Particles
Charged particles emitted in radioactive decay and nuclear fission. Negatively charged bega particles are electrons. Beta rays. (See Radioactivity.)

Chain Reaction
A self-sustaining sequence of nuclear fissions taking place in a reactor core. The reaction that occurs when a neutron splits an atom, releasing enough neutrons to cause other atoms to split in the same way.

Condenser
A device used in most power plants to re-convert steam to water after the steam has passed through the turbine-generator.

Containment
The structure, usually of reinforced concrete, designed to isolate fission products from the environment in the event of a major nuclear accident. At Fort St. Vrain, the prestressed concrete reactor vessel's inner cavity and the primary closures serve as primary containment. Secondary containment is provided by the massive PCRV and secondary closures.

Control Rods
Boron carbide and graphite rods which control the amount of power generated at Fort St. Vrain. As the rods are withdrawn from the reactor, more heat is produced; as they are inserted, less heat is produced. Fort St. Vrain has 37 control rod drives, each one operating two control rods.

Coolant
The medium which withdraws heat from the reactor core. At Fort St. Vrain, the coolant is helium, an inert gas that rises into the atmosphere when released.

Core
Also reactor core. The innermost part of a nuclear reactor which contains the nuclear fuel. The Fort St. Vrain core is made of graphite blocks which hold the fuel.

Critical
Term used to describe a nuclear reactor in which a chain reaction is taking place.

Curie
Unit of radioactivity, abbreviated Ci. The amount of radioactivity associated with one gram of radium. A picocurie is one-trillionth of a curie, a nanocurie, one-billionth, and a microcurie is one-millionth.

Decay
The process of radioactive disintegration.

Decay Heat
The heat produced by the decay of radioactive particles. In a nuclear reactor decay heat, which results from the materials left over from the fission process, must be removed after reactor shutdown to prevent the core from being damaged.

DODES
The Colorado Division of Disaster Emergency Services, the state agency which would be in charge of implementing the Fort St. Vrain Emergency Response plan in case of an accident at the plant which might have an effect on the public. DODES is responsible for offsite emergency response management. The Nuclear Regulatory Commission (NRC) is the federal agency that oversees the company's on-site response plan.

Dose
A term used to express the amount of radiant energy absorbed in tissue. (See rem.)

Dosimeter
A device for measuring radiation dose.

ECCS
Emergency core cooling system. A reactor safeguard or emergency system designed to return coolant to the reactor core in the event of a loss of coolant accident.

Electrons
Fundamental negatively charged particles, present in all matter.

Feedwater System
Water supply to the steam generators that is converted to steam by heat from the reactor. The steam, in turn, is used to drive turbines, which generate electricity.

Fission
The nuclear process in which a heavy atom such as uranium splits into fragments, which releases large amounts of energy, creating heat.

Fission Products
The name given to atomic fragments created by nuclear fission. These products are usually radioactive.

Fuel
At Fort St. Vrain, the fuel is a uranium-thorium combination. In pellet form, the fuel either contains a uranium-thorium mixture or thorium alone. In its natural state, thorium does not fission, but when bombarded by neutrons, it is changed into U-233, a fissionable material, just as U-235 is fissionable. Fort St. Vrain contains about 39,000 pounds of thorium and less than 2,000 pounds of uranium.

Fuel Elements
Elements which contain a nuclear plant's fuel. Fort St. Vrain has 1,482 graphite fuel elements, hexagonal in shape, which contain the uranium and thorium fuel particles. Graphite is used because it becomes stronger as it becomes hotter, providing additional safety.

Gamma Rays
Penetrating electromagnetic radiation emitted in radioactive decay. Similar to x-rays. (See Radioactivity.)

Half-Life
Term used to describe the time rate of radioactive decay. A single half-life is the time required for an initial amount, say 100 units, of radioactivity to decay to 50 units. Two half-lives will see the initial 100 units decrease to 25 units and so on.

Helium
The element used to cool the reactor at Fort St. Vrain. An inert gas, that is, a gas lacking the properties to be affected by chemical or biological action, rises to the upper atmosphere when released. Helium is not toxic, nor does it constitute a fire or explosion hazard. Using the helium gas as a coolant allows Fort St. Vrain to operate at very high temperatures, typically 1300-1500 degrees Fahrenheit.

Helium Circulators
The devices which send helium through the core of the reactor to cool it. Fort St. Vrain has four helium circulators, each capable of attaining 5,500 horsepower. The circulators are positioned below the reactor core. Each circulator has an auxiliary drive which can be used to supply power to the circulator when the steam supply is either not available or not desirable.

HTGR
High temperature gas-cooled reactor. Fort St. Vrain is the only HTGR in the United States. It is called a gas-cooled reactor because it uses helium instead of water.

LOCA
Loss of coolant accident. When all or part of the helium coolant is lost.

Meltdown
In reactors that have a metal core and use water as a coolant, "meltdown" refers to the situation when all or part of the water is lost and the metal core melts from the heat. This cannot happen at Fort St. Vrain because the core is graphite, which will not melt. Graphite becomes harder as its temperature increases.

Millirem
A unit used to measure radiation doses. It is 1/1000th of a REM which stands for Roentgen Equivalent Man, a measure of radiation that indicates its impact on human cells.

Natural Radiation
Also called "background" or "background radiation." Man's naturally occuring radioactive background, usually about 1/10th rem per year due to radioactive materials in the earth and air plus the effect of cosmic rays. In Colorado, the natural background radiation is about 200 millirems (1/5th rem) yearly, higher than many other areas because of the mile-high altitude and commensurate higher exposure to cosmic radiation from the sun.

Noble Gases
Those gases that do not react chemically with other elements. They are: helium, xenon, krypton, neon, radon, and arcon.

Neutron
A fundamental atomic partical having no electrical charge. Neutrons are required to initiate the fission process and large numbers of neutrons are produced during the fission process.

NRC
Nuclear Regulatory Commission. The federal agency charged with enforcement of regulations in the nuclear industry.

PCRV
Prestressed Concrete Reactor Vessel. The PCRV at Fort St. Vrain contains the coolant in the reactor and provides radiological shielding. Access to the reactor is through the PCRV. The upper and lower heads of the PCRV are 15 feet thick, and the walls average nine feet thick. The PCVR is a steel tendon-reinforced concrete cylinder weighing 17,000 tons and buried halfway underground. The tendons are "live," meaning that any crack in the concrete, however caused, would immediately reseal.

Pellet
Also fuel pellet. Uranium-thorium little finger-sized pellets that are the fuel for Fort St. Vrain. (1.5 inches long and 0.4 inches in diameter.) The pellets are stacked on top of each other and inserted in the graphite structure to form the fuel element.

RAD
A unit used to measure an absorbed dose of radiation.

Radioactivity
Radioactivity is the property possessed by some elements that spontaneously give off energy in the form of waves or particles. Radiation may be alpha, beta, or gamma. Alpha radiation is the least penetrating type. It can be stopped by a sheet of paper. Beta radiation is emitted from the nucleus of an atom during fission. It can be stopped by thick cardboard. Gamma radiation is electromagnetic waves emitted from a nucleus and is essentially the same as X-rays. It can be stopped by heavy shielding such as lead or concrete.

Sources and amounts of natural background radiation
(Measured in Millirems per year)

Cosmic Rays	35
Air	5
The Earth	11
Food	25
Building Materials	34
Living in Denver	200

Sources and amounts of man-made radiation
(Measured in Millirems)

Dental X-rays	
Bitewing Series	400
Panoramic	500-1000
Whole Body X-ray	25000
Coast-to-Coast Airline Flight	5
Color Television	1 per year
Living next to a Nuclear Plant	Less than 1 per year

NRC allowable radiation exposure to PSC employees working at Fort St. Vrain — 5000 millirems/year.

Radioiodine
A radioactive form of iodine, predominantly iodine-131, formed in fission and released in the reactor cores.

Reactor
Equipment in which a self-sustained chain reaction takes place. The reactor at Fort St. Vrain is comprised of the PCRV, support floor, control rods, reflector, core, steam generators and helium circulators.

Refueling Penetrations
Refueling penetrations extend from the top of the reactor to its core and are used to gain access to the fuel when it is exhausted and needs to be replaced with fresh fuel.

REM
A unit of radiation dose. Stands for roentgen equivalent man. Equal to product of rads times relative biological effectiveness of the particular type of radiation. A millirem is equal to 1/1000th of a rem.

RERP
Radiological Emergency Response Plan. Plans drawn up by operators of nuclear plants and appropriate state officials to deal with any contingency at a nuclear plant which could result in an unplanned release of radiation or other possible danger either to the public or the plant personnel.

SCRAM
Term applied to the sudden shutdown of a nuclear reactor. Usually accomplished by the insertion of safety control rods. Also called reactor safety trip. A scram does not necessarily imply an emergency. Fort St. Vrain's "scram insertion time" is 180 seconds.

Steam Generators
Devices that make steam. At Fort St. Vrain, water in the steam generators is converted to steam as helium gas, heated to 1,430 degrees, flows over the plant's 12 steam generator modules. The steam generators are located under the reactor core. Steam from the generators is at approximately 1,000 degrees.

Turbine Generator
The device in a power plant which uses the force of steam to produce electricity. The steam turns the turbine which turns the electricity-producing generator.

Thorium
A relatively cheap, non-fissionable element in its natural state. At Fort St. Vrain, the fuel is about 20 pounds of thorium for every pound of uranium. When bombarded by neutrons, as it is at Fort St. Vrain, thorium is changed into U-233 which is fissionable.

Whole Body Count
Evaluation of all radioactive material contained in a body from both natural and man-made sources.

Whole Body Exposure
An exposure of the body to radiation. Where a radioisotope is uniformly distributed throughout the body tissues rather than being concentrated in certain parts, the irradiation is considered to be whole body exposure.

PLACE A 15¢ STAMP HERE

TO:
Weld County Sheriff
P.O. Box 759
Greeley, CO 80632

From: ____________________

____

____

If You Have Special Needs Fill Out and Mail This Card

I am hard of hearing Yes ☐ No ☐

I am visually impaired Yes ☐ No ☐

I am (otherwise disabled) ____________________

____

I would like special notification of any emergency
Yes ☐ No ☐

I would need transportation Yes ☐ No ☐

Other special needs (explain) ____________________

____

____

Name ____________________

Address ____________________
(Rural address or street number)

City ____________________

Telephone ____________________

Any special directions to get to your house? ____________________

____

____

For example: I live on the north side of county road 46, in the second house west of county road 31.