PR- 50, 52
85 FR 28436

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From: MH Specter
To: RulemakingComments Resource
Subject: [External_Sender] ATTN: Chairman Svinicki, Emergency Planning for SMRs and ONTs
Date: Monday, July 20, 2020 12:09:08 PM
Attachments: Comments on Emergency Preparedness for SMRs and ONTs.pdf

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Kristine L. Svinicki
Chairman
Nuclear Regulatory Commission

Dear Chairman Svinicki:

Attached are my comments on the proposed rule on Emergency Planning for SMRs and ONTs. This submittal provides specific recommendations on emergency planning for SMRs and ONTs and also a general review of the very low radiological risks presented by nuclear power plants, regardless of their designs.

If I can be of further help, please contact me.

Sincerely,
Herschel Specter, President
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MICRO
UTILITIES

Comments on Emergency Planning For SMRs and ONTs

July 2020

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ABOUT THE AUTHOR

Herschel Specter, President of Micro-Utilities, Inc., holds a BS in Applied Mathematics from the Polytechnic Institute of Brooklyn and a MS from MIT in Nuclear Engineering. He is a Licensed Professional Engineer in the State of New York. He has had a long association with the Indian Point nuclear power plants starting as a member of the Atomic Energy Commission (now the Nuclear Regulatory Commission) where he was the Licensing Project Manager for the original licensing of the Indian Point 3 nuclear plant in the 1970s. In the 1980s the New York Power Authority hired Mr. Specter to manage the defense of Indian Point 3 in a federal adjudicatory trial in the wake of the Three Mile Island nuclear accident in Pennsylvania. Prior to joining NYPA, Mr. Specter served at diplomat rank for 5 years at the International Atomic Energy Agency in Vienna, Austria where he headed up an international effort writing design safety standards for nuclear power plants.

Mr. Specter has been Chairman of two national committees on emergency planning and was a guest lecturer for several years on emergency planning at Harvard’s School of Public Health. He led an effort as a consultant to Entergy analyzing emergency responses during a hypothetical terrorist attack on Indian Point. Mr. Specter has presented testimony at the National Academy of Sciences on the Fukushima accident and on other nuclear safety matters and has been a guest speaker at many universities on matters of energy policy. Today he is one of 14 Topic Directors in Our Energy Policy Foundation, a group of about 1500 energy professionals who seek to bring unbiased and comprehensive energy information to our political leaders and members of the public.

Mr. Specter has been active on social and environmental matters. He has been a Big Brother and in 1971 had the honor of being selected as “Big Brother of the Year” for all of the USA and Canada. He also received a personal letter of commendation from the President of the United States for his work with the Youth Conservation Corps.

Mr. Specter was born in White Plains, NY and lives there now.

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Comments on Emergency Preparedness for SMRs and ONTs

1.0 Executive Summary

The purpose of this document is to offer recommendations on emergency preparedness for Small Modular Reactors (SMRs) and Other New Technologies (ONTs). In developing these recommendations a long-standing basic principle expressed by the Environmental Protection Agency was utilized: emergency plans should be designed to minimize the sum of the radiological risks from an accident and the non-radiological risks incurred by the actions taken to reduce the radiological risk.

As a first step, a review of the radiological risks from existing light water reactors (LWRs) was examined for lessons learned that might apply to SMRs and ONTs. It became apparent that both the health risks and health consequences to the public from radiological events from LWRs was close to zero. LWRS are far more benign than many people realize. This conclusion was reached after examining numerous accident analyses and the health consequences of actual nuclear accidents. This review of LWRs included PWRs, BWRs, and the Chernobyl design. Not only were a variety of plant designs examined, but also different accident scenarios were considered, such as station blackout, pipe breaks, and power excursions. This review looked at analytical studies, the NRC’s sponsored SOARCA program, postulated successful terrorist attacks sponsored by a nuclear utility, and the consequences of four actual accidents. Even different emergency responses were examined, including a non-response where one extreme analysis assumed that people would stand out-of-doors for 48 hours while an accident was in progress. In spite of the wide swath of this investigation, i.e., different reactor designs, different accident scenarios, different emergency responses, analytical studies and actual accidents, the recurrent conclusion was that it is very difficult to create a situation where off-site people might become early fatalities from radiation from a nuclear accident. Even radiation-caused temporary radiation sicknesses seem unlikely.

Much of the material in this document comes from studies of the Indian Point site, the nation’s most populous site, the site examined years ago in the Sandia Siting Report, and also the site that has been subjected to fear mongering about emergency responses.

This review went into additional detail by examining why these health consequences were so low. Certainly design specific engineered safety systems need to be credited in making the probability of a release of radioactive material into the environment quite small. Other engineered safety features, like containment sprays, are designed to reduce the size of the source term. However, there are other beneficial consequence-reducing processes that are not man-made, but rather the result of natural forces. These naturally occurring consequence-reducing processes are quite important because many of them apply regardless of the reactor design or accident sequence. They cannot be defeated by operator errors or by acts of terrorism. Among the on-site natural forces discussed in this document are gravity, the plating out of radioactive material on metallic surfaces, radioactive material being absorbed in wet surfaces and in water pools. Off-site, there are natural consequence-reducing forces including the thinning out of radioactive plumes with distance because of diffusion, meteorological forces that cause wind shifts, and human biology that requires high levels of exposure to cause early health effects.

Since the radiological risks from nuclear power are so low by design and by natural forces, what then is the value of emergency planning for the very safe SMRs and ONTs? Three reasons are offered. One only has to look to the emergency response to the Fukushima accident. Initially the

Japanese evacuated the innermost two miles surrounding Fukushima prior to the release of radioactive material. By doing this they eliminated the early fatality and radiation sicknesses risks. Unfortunately, they later over-evacuated, causing over 1,000 non-radiological fatalities. If SMRs and ONTs had, in effect, a very limited emergency response plan and a nuclear accident occurred, people might evacuate on their own, creating possible non-radiological consequences. A second reason to have some kind of an emergency plan is that nuclear accidents typically involve some sequence of events that had either been unforeseen or dismissed because it was too unlikely to be risk relevant. Therefore an emergency plan offers defense-in-depth for very rare or unforeseen events. Third, there is the matter of public acceptance. Without public acceptance the deployment of SMRs and ONTs may be delayed. Some emergency plan is needed that offers public protection, but is comparatively simple to implement.

What emergency plan for SMRs and ONTs would minimize the non-radiological risks, be simple to execute and effective, would not place an undue financial burden on the plant operator, and could garner the trust of the public? **It is suggested that the best overall fit to these goals is an plume exposure pathway EPZ with a radius that extends two miles beyond the site boundary and that sheltering, not evacuation, be the dominant emergency response within this EPZ.**

This report also identifies potential improvements in the emergency plans for LWRs. If implemented, these improvements should reduce non-radiological risks and establish an overall approach to emergency planning that encompasses LWRs, SMRs, and ONTs and which recognizes their similarities and their differences.

2.0 The Basic Principle of Emergency Preparedness

Regardless of the nuclear technology used to produce electricity and/or heat there is an underlying emergency preparedness principle that should be applied to all. This fundamental principle was expressed in a 1990 document by the Environmental Protection Agency (1):

“The decision to advise members of the public to take actions to protect themselves from radiation from a nuclear accident involves a complex judgement in which the risk avoided by the protective action must be weighed in the context of the risks involved in taking the action.”

This EPA guidance is fundamental because it addresses both radiological and non-radiological risks associated with developing an emergency plan. Clearly the public is best served when the sum of the radiological plus non-radiological risks is minimized. Almost all of the comments on the NRC proposed rule for emergency preparedness for Small Modular Reactors (SMRs) and Other New Technologies (ONTs) focus on the radiological risks that emergency preparedness is intended to reduce.This is too narrow a view of the role of emergency preparedness.

For example, the initial emergency response to the off-site radiological risk during the accident at Fukushima, Japan was excellent, resulting in radiological consequences close to zero. This was accomplished by evacuating the innermost two miles from Fukushima prior to the release of any radioactive material into the environment. This pre-emptive evacuation of a small local area eliminated the risks of radiation causing any early fatalities or sicknesses. However, the subsequent emergency response at Fukushima was a failure and over 1,000 people died from non-radiological causes because of this. This large non-radiologically consequence at Fukushima was the result of over-evacuation, followed by very poor sheltering conditions for evacuees, evacuee fears of having been irradiated, and the depression brought about by the presumed loss of homes and farms that had been held by the same family for hundreds of years. Once told to evacuate, eighty thousands of sheltered people even three years later refused to return to their original homes although government officials told them it was safe to do so. Mistrust in the Japanese government on this issue was/is significant. Details on the sequence of the emergency response at Fukushima are provided in the Appendix A of this report.

Had the above basic EPA principle been incorporated into the emergency plan for Fukushima and clearly understood by senior decision-makers who promoted over-evacuation, much of these non-radiological consequences might have been avoided. As discussed later in this report, the off-site radiological risks and consequences from accidents in US nuclear power plants are extremely small regardless of the emergency response. Therefore modern emergency plans should emphasize minimizing non-radiological consequences. When non-radiological consequences are minimized this may also reduce off-site radiological consequences. Simple, but effective, emergency response plans should gain public confidence and support. Both LWRs and Small Modular Reactors and ONTs should have emergency plans where the primary response is sheltering.

3.0 LWRs, SMRs, and ONTs

It would be advantageous to apply the above emergency planning basic principle to LWRs, SMRs, and ONTs, taking into account their similarities and their differences.

3.1 Similarities Among LWRs, SMRs, and ONTs

3.1.1 Time Delays

Some have argued that SMRs enjoy advantages over LWRs such as passive capabilities, and that "the SMR design results in a significant time delay before any release to the environment can occur; thereby allowing for additional actions that could mitigate or preclude any release."(2)

Without question these are very favorable SMR safety characteristics. However, these characteristics are also shared by many LWRs. For example, accident analyses for a large Pressurized Water Reactor in the SOARCA program showed that the time between the initiation of a short term station blackout sequence, without any operational active safety equipment or operator actions (no mitigation), and the time when radioactive material might begin to enter the environment was calculated to be 25.5 hours. The time for radioactive material to begin to enter the environment for the long term SBO was calculated to be 45.3 hours.(3) It appears that all US nuclear plants would exhibit significant time delays between accident initiation and the start of radioactive material entering the environment. All nuclear designs with sturdy containment buildings and a negative power coefficient should have long time delay characteristics. These SOARCA calculated time delays appear in TABLE A-1, below, for a PWR with a large dry containment:

TABLE A-1 SST-1 and SOARCA Release Fractions

	Core damage frequency, events/yr.	Tellurium release fraction	Iodine release fraction	Cesium release fraction	Release enters environment, (time delay), hours	Release ends, hours
SOARCA short term station blackout, 2012	$2x10^{-6}$	0.006	0.006	0.001	25.5	48.0
SOARCA long term station blackout, 2012	$2x10^{-5}$	0.006	0.003	0.000	45.3	72.0
SST-1 in 1982	$1x10^{-5}$	0.640	0.450	0.670	1.5	3.5

In TABLE A-1, SST-1 is the largest source term analyzed in the Sandia Siting Report.(4) The SOARCA program, also conducted by the Sandia National Laboratory, is an update of the original Sandia Siting Report. The SOARCA program came to three major conclusions that are reflected in Table A-1. Compared to the original Sandia Siting Report, the release of radioactive material into the environment from an accident at a nuclear power plant:

A. would be far smaller,

B. would be significantly delayed, and

C. would take place over a longer time period.

Each of these SOARCA conclusions is important to establishing an emergency plan. First, such small source terms are not capable of producing the high radiation doses necessary to cause an early fatality and may not be large enough to cause any radiation sickness, regardless of the emergency response. Second, the long time period between the initiation of an accident sequence and the release of radioactive material provides more time for onsite personnel to take mitigative actions, while the offsite emergency team would have more time to implement protective actions like assisting people to take shelter or in evacuating areas close to the damaged power plant. Third, the more gradual release of radioactive material into the environment increases the probability that the wind direction will shift one or more times during the extended release period. As discussed later, changing wind direction reduces the probability of causing an early fatality or radiation sickness. However, unless properly planned for, changing wind direction could increase the non-radiological consequences by taking actions that were intended to reduce radiological risks.

The three major conclusions reached by SOARCA were borne out by the Fukushima accident, as shown in TABLE A-2.(5)

TABLE A-2 Measurements From Fukushima Support SOARCA Analyses

Fraction of Core Inventory	Iodine	Cesium
SST-1	0.450	0.670
Fukushima	0.017-0.083 (Smaller than thought before.)	0.009-0.029 (Smaller than thought before.)
	Start of release	Duration of release
SST-1	1.5 hours	2.0 Hours
Fukushima	Earthquake on March 11, 2011; release starts on March 12, 2011, more than 12 hours later. (Later than thought before.)	March 12, 2011 to March 25, 2011. (More gradual than thought before.)

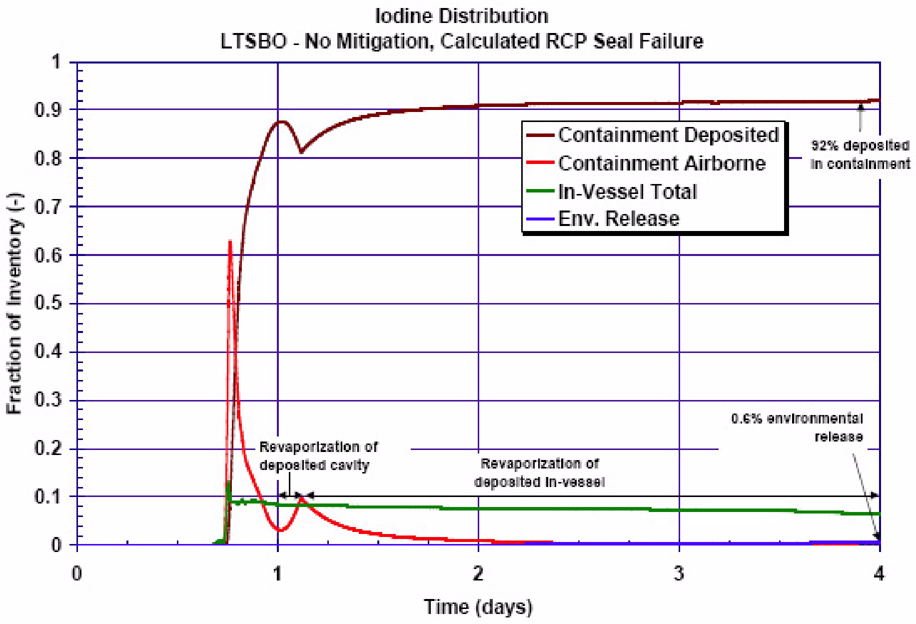
3.1.2 Passive Features

SMRs and ONTs are credited with having redundant passive features. These are attractive safety features. The most important passive safety feature in LWRs is the containment building. An example of the safety significance of the passive containment buildings in LWRs is shown in the SOARCA analyses that examined the different station blackout sequences described in TABLE A-1. The calculated release fractions in this table for this type of LWR are so small, that if smaller source terms could be achieved by SMRs and ONTs, they would have no important radiological or emergency planning benefit.

The SOARCA analyses results listed in TABLE A-1 are based on core melt scenarios where no engineered safety systems were assumed to be operable because of a total station blackout. No credit was given for operator actions to mitigate these hypothetical accidents. As the core melt sequence progressed, a gradual pressure buildup in the containment was calculated, leading to significant leakage from the containment into the environment after 25.5 or 45.3 hours. The calculated releases of iodine and cesium, and others, were very small. This is because natural forces like gravity, plating out on metal surfaces, and entrapment in wet surfaces and within pools of water created by the accident greatly reduce airborne concentrations of airborne radioactive material inside the containment in the time period before containment leakage becomes significant. These natural removal processes are passive in the sense that they do not need electric power or operator actions. They cannot be defeated by operator errors or acts of terrorism.

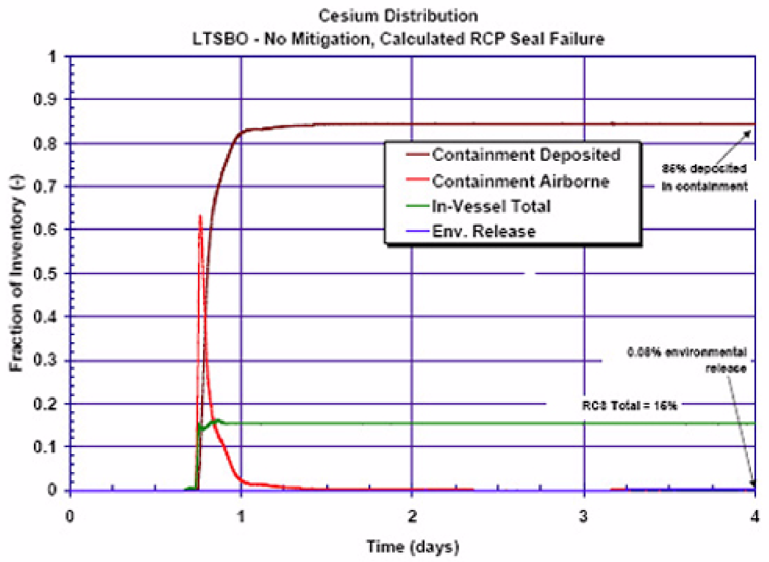
FIGURE A-1 depicts the airborne iodine concentration as a function of time for a large dry PWR containment during a long term station blackout sequence where significant containment leakage does not begin until 45.3 hours after accident initiation. Note that the iodine concentration in the containment air space reaches high levels around the time of reactor vessel failure. However, these airborne iodine concentrations rapidly decrease after their peak because of the above natural removal processes. This rapid drop off in iodine airborne concentrations occurs before there is significant containment leakage. Airborne concentrations in the containment air space for cesium and other fission products have profiles similar to that of iodine. See FIGURE A-2.

FIGURE A-1 Iodine Distribution, Long Term Station Blackout



Unmitigated LTSBO iodine fission product distribution history

FIGURE A-2 Cesium Distribution, Long Term Station Blackout



Unmitigated LTSBO cesium fission product distribution history

3.1.3 Consequence Reduction with Increasing Distance

There are multiple ways of reducing a person’s dose in addition to evacuation and sheltering. Two natural process that would reduce doses are diffusion and wind direction changes. Diffusion is a natural process that is easily observable. Plumes thin out and widen as they move away from their points of release. This means that a person under a radioactive plume that is further away from the point of release would get a smaller dose, i.e., distance reduces the dose rate.

Because the dose rate decreases with distance, distance alone from a damaged nuclear power plant is sufficient to limit the range of the early health effects. Regardless of the size of the radioactive release, there is always some distance at which radiation exposures fall below the threshold of an individual becoming a near term fatality. Reviews of different accident analyses and actual accidents place this limiting distance between zero and one mile for near term fatalities and zero and two miles for radiation sicknesses.

3.1.4 Consequence Reduction Because of Wind Shifts and Long Release Times

In addition to the dilution effects of distance, lower downwind doses would occur if there are wind shifts during the long duration of the release of a radioactive plume from a nuclear accident. As shown in TABLE A-1, the durations of the releases of radioactive material into the environment are calculated to be 22.5 hours and 26.7 hours for the short term station blackout sequence and the long term station blackout sequence, respectively. If a wind shift ended up with the radioactive plume covering twice the area compared to the area covered by plume with a steady wind direction, exposed individuals would get only half the dose. FIGURE A-3 can be used to illustrate the importance of thresholds to wind shifts.(6) Assume that a person experiencing a steady wind direction received a very high dose of 3 Grays. In this hypothetical situation, according to FIGURE A-3 with minimal medical treatment, there would be about a 50% chance that this very exposed individual would become an early fatality. Now take another hypothetical case where the wind has shifted so that two individuals each receive half the dose, 1.5 Grays, of the first individual who received 3.0 Grays. Figure A-3 indicates that these two individuals with half the dose each would be below the threshold for near term fatalities. In this hypothetical example the chances of causing a near term fatality from exposure to radiation decreased from 50% for one individual to 0% for two individuals. Even though the same amount of radioactive material was released into the environment in these two hypothetical cases, wind shifts can significantly lower calculated early health risks from nuclear accidents.

Actual meteorological data taken at the Indian Point nuclear power plant provide more insights. These meteorological data are plotted in FIGURE A-4.(7) At this site, on average, there is about a 50% chance that the wind will shift one sector (22.5 degrees) during the next hour. Every four hours, on average, there is a 50% chance the wind will shift the wind will shift three sectors (67.5 degrees) and in ten hours there is a 50% chance that the wind will shift 7 sectors. Considering the very long times now calculated for the gradual release of radioactive material (See TABLE A-1), wind direction changes make it less likely that anyone can acquire high doses. The Fukushima and Chernobyl accidents showed evidence of changing wind directions during the time there were radioactive plumes,

FIGURE A-3 Risk of Mortality Versus Radiation Exposure

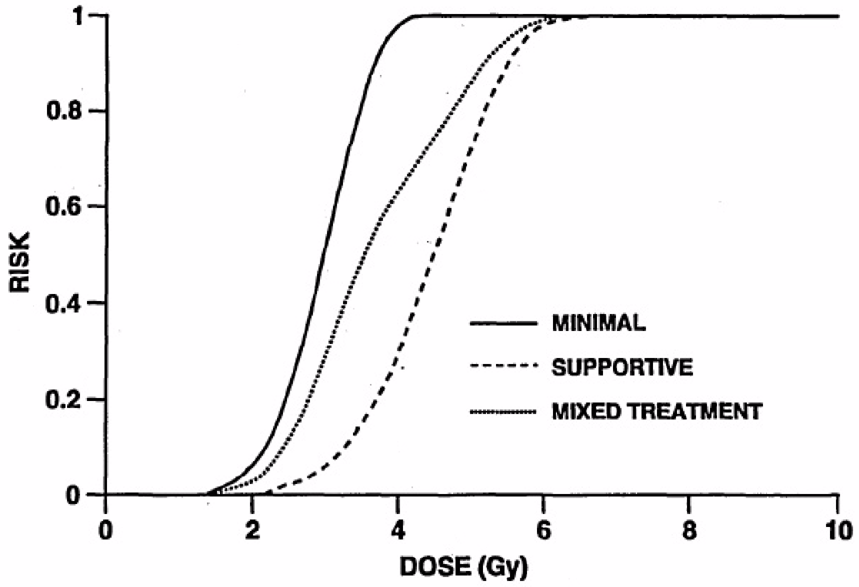
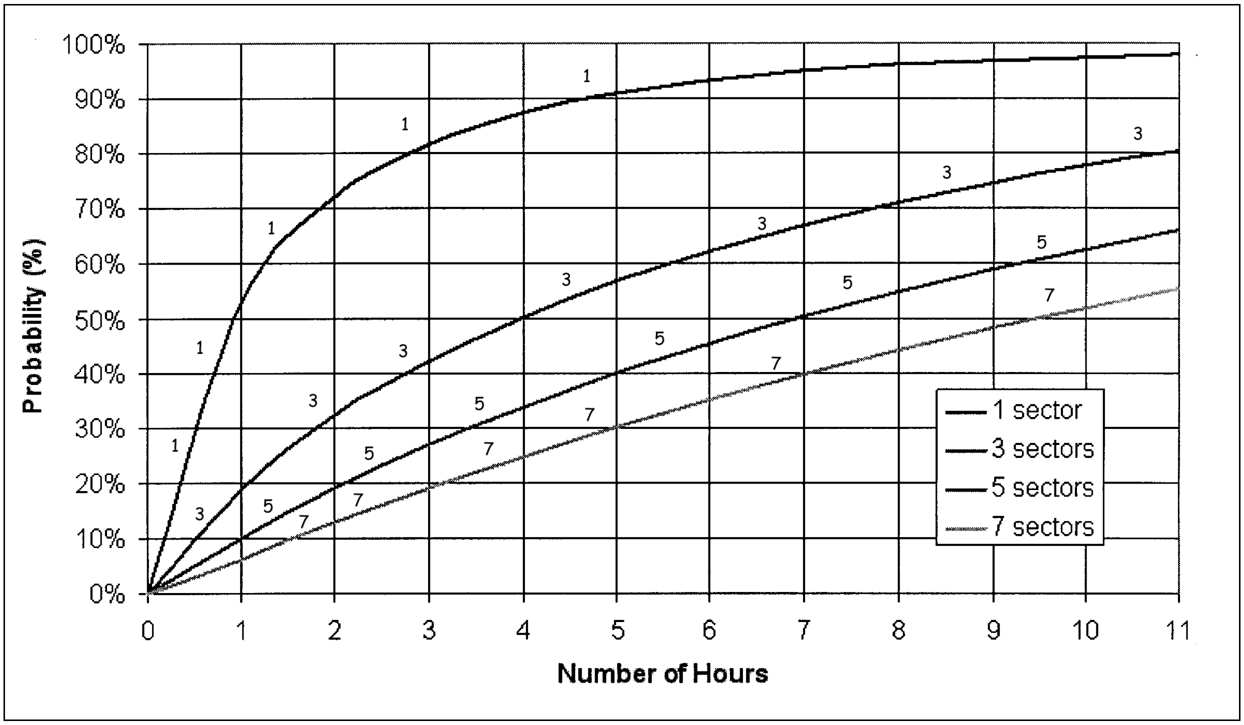


Figure 3.1 Risks of mortality from the hematopoietic syndrome for minimal, supportive, and mixed treatments: central estimates for exposure at a high dose rate.

FIGURE A-4 Probability of Wind Shifts at Indian Point



3.1.5 Actual Accident Consequences

In addition to the insights gained from SOARCA and other analytical studies, there are insights from four actual nuclear accidents, listed in TABLE A-3. These accidents occurred in a variety of nuclear designs, a large dry PWR, Mark I BWRs and the Russian Chernobyl design which included graphite in the reactor core. In spite of very different designs and accident sequences there were no off-site early fatalities. The 28 early fatalities at Chernobyl were the result of on-site exposure to radiation. The consequences from these four accidents support the conclusion that off-site near term fatalities from radiation exposure is extremely unlikely to occur.

TABLE A-3 Radiological Consequences From Four Nuclear Accidents

Power Plant	**On-site** near term fatalities	**Off-site** near term fatalities	Long term fatalities	Comments
Browns Ferry	0	0	0	Reactor fuel never damaged, no releases to the public.
Three Mile Island	0	0	0	Reactor meltdown, no significant leakage.
Fukushima	0	0	Would be too small to be detected, even when conservatively calculated.	3 Reactor meltdowns, containment leakage after 12 hours. Containment building and emergency diesels survive magnitude 9 earthquake. Tsunami causes station blackout. Only small releases of iodine and cesium, consistent with modern accident analyses.
Chernobyl	28	0	No observed cases of leukemia, even after 30 years. Thyroid cancers among children in Belarus, Russia, and the Ukraine.	Rapid power excursion, burning graphite, no containment building, an extremely limited confinement building. Contamination of nearby land and property, some of which still kept off-limits. Thyroid cases caused by drinking contaminated milk, 99+% successfully treated. This consequence would not happen in the US or elsewhere (e.g. Japan) because of contaminated food interdiction programs.

3.1.6 Summary

With very low probabilities of having a core melt sequence coupled with very small releases of radioactive material into the environment, should a core melt sequence happen, means that LWRs, SMRs, and ONTs all present very small risk profiles. These very small risk profiles are achieved by design within the nuclear plants themselves and by natural forces acting within the containment buildings that limit potential releases of radioactive material into the environment. Further, naturally occurring, consequence- reducing actions take place outside of the nuclear plants. Diffusion widens accident plumes with distance from the point of release. Meteorological forces cause wind shifts that lower potential radiological consequences, as does human biology that requires very large exposures to radiation to cause an early health effect. Because of these naturally occurring inherent consequence-reducing actions, emergency plans should be simple and should emphasize sheltering to avoid non-radiological risks due to over-evacuation.

3.2 Differences Between LWRs and SMRs, ONTs

The very small risk profiles described above applies to postulated accident sequences. However there can be accident sequences that were judged to be so unlikely they were ruled out because they were considered to be not risk significant. Further, there are “unknown unknowns” i.e., accident sequences that were not envisioned in the plant’s design or during power operation. Historically such “unknown unknowns” were dealt with by having safety margins and by having defense-in-depth. More recently post-Fukushima safety additions have increased the ability to deliver electricity and cooling capacity at numerous locations throughout a nuclear power plant. This additional flexibility also serves to reduce the potential importance of “unknown unknowns”.

However, it appears that the highly passive designs and other features of SMRs and ONTs may make them better suited to deal with these rare “unknown unknowns” than LWRs. LWR emergency plans need to be simplified and the emergency plans for SMRs and ONTs should be even simpler to implement than LWR emergency plans.

4.0 Metrics

4.1 Introduction

How should different possible emergency plans and actions be evaluated? In this section the use of PAGs (Protective Action Guides), the early fatality risk, and the radiation sickness risk are examined.

4.2 PAGs

It is suggested that the concept of PAGs in emergency planning be eliminated. If the PAG concept is to be kept, then the action to be taken, if a PAG exceeding one rem total effective dose equivalent (TEDE) is projected, should be to take shelter and not to evacuate. There are a number of reasons for this. As the footnote on page one of the letter from Dr. Baranwal to Chairman Svinicki pointed out “As a reference point, one rem TEDE is approximately equivalent to receiving a Technetium nuclear cardiac stress test or a Barium contrast for a gastrointestinal X-ray procedure”. Since the medical community has judged that such a small dose is acceptable and such medical procedures occur far more frequently that core melt accidents one rem doses are not important enough to be a major factor in emergency planning. Certainly, they are not nearly as important as avoiding over-evacuations.

The development of Emergency Preparedness Regulations for SMRs and ONTs is supposed to adopt a “consequence-oriented, risk-informed, performance-based and technology-inclusive approach”.(8) A one rem TEDE is not sufficiently consequence-oriented to be used in a decision making process in emergency planning. If one accounts for the very small probability of a release of radioactive material expected from SMRs and ONTs, then the product of probability times the limited consequences of a one rem TEDE is miniscule and has no place in modern emergency planning.

There are other issues with one rem whole body doses. TABLE A-4 is an adaptation of Table 2.3.1-2 of the Sandia Siting Report (NUREG/CR-2239) which describes different source terms used in that report. SST-1,-2, and -3 represent core melt sequences. SST-4 and SST-5 are gap release source terms and are not important for emergency planning purposes. Only the release fractions of Iodine, Tellurium and Cesium are listed in TABLE A-4 because other release groups, Xe-Kr, Ba-Sr, Ru and La, are not important to developing an emergency plan.

TABLE A-4 Release Fractions For NRC Source Terms used in Siting Analyses,

Release Group	SST-1	SST-2	SST-3
I Group	0.45	$3x10^{-3}$	$2x10^{-4}$
Cs-Rb Group	0.67	$9x10^{-3}$	$1x10^{-5}$
Te-Sb Group	0.64	$3x10^{-2}$	$2x10^{-5}$

TABLE A-5 is derived from Figure 2.6-5 of the Sandia Siting Report and shows the calculated distance out to which a one rem whole body dose would be expected at a conditional probability of 10^{-2}. To arrive at the absolute probability of having a one rem whole body dose at these distances, multiply the calculated accident probability by 10^{-2}. For example, The Sandia Siting Report assigned a probability of a SST-1 occurring at $1x10^{-5}$/reactor year. Therefore the absolute probability of an SST-1 producing a one rem whole body dose at the distance listed in TABLE A-5 is 10^{-7} per reactor year.

TABLE A-5 One Rem Whole Body Dose Versus Distance (Miles)

Source Term	Distance at Which a One Rem Whole Body Dose Might Occur at a 10^{-2} Conditional Probability, Miles
SST-1	~300
SST-2	~ 40
SST-3	2

Radioactive iodine is the dominant contributor to potential early health effects. The release fractions for iodine in the station blackout scenarios presented in TABLE A-1 are 0.003 and 0.006. These release fractions for iodine would be comparable to the iodine release fraction for an SST-2 source term. At a conditional probability of 10^{-2}, the iodine released from a SOARCA station blackout scenario implies that a one rem whole body dose might occur out to about 40 miles.Even at a conditional probability of 10^{-1} the distance out to which a one rem whole body dose might occur is about 25-30 miles. See Figure A-5.(9)

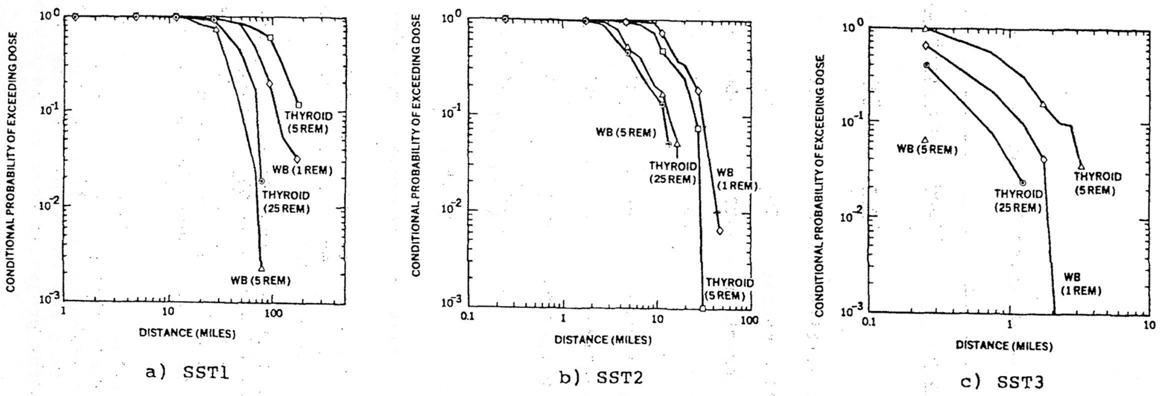
Even if the SMR and ONT source terms resembled the SST-3 source term, a whole body dose of one rem would extend to about 2 miles at a conditional probability of 10^{-2}. Further the calculated source terms in TABLE A-5 are point values. Modern accident analyses often include uncertainty analyses which show a distribution of results, larger or smaller than the mean value. Such uncertainty analyses, if applied to the calculation of source terms or if applied to the meteorological conditions, would result in a different presentation than that in TABLE A-5. Instead of a single point value for a one rem whole body dose at some calculated distance from the point of release at a specific conditional probability, there would be a range of possible distances.

Based on past experience it is possible that opponents to SMRs or ONTs would select the longest PAG related distance using such uncertainty analyses. For example, groups opposed to the Indian Point nuclear power plants have misrepresented the areas that might have to be evacuated, calling for a 50 mile evacuation zone for Indian Point. First, instead of the 10 mile radius called for in the NRC guidelines for the Plume Exposure Pathway EPZ, a 50 mile radius was talked about. It appears that Indian Point opponents inappropriately substituted the 50 mile radius from the Ingestion Exposure Pathway EPZ for the 10 mile radius of the NRC's Plume Exposure Pathway EPZ. Second, although the letter **E** in **E**PZ stands for **E**mergency, opponents talked about as if the letter **E** stood for **E**vacuation. When combined, this misinformation became the 50 mile Evacuation Zone. There are about 20 million people within 50 miles of Indian Point and this led to the fiction that Indian Point should be closed because it is near impossible to evacuate 20 million people if there were an accident. No professional emergency planner would ever call for such a massive and dangerous evacuation. This false distance was even repeated by former NRC Chairman Jaczko when advising Americans in Japan to evacuate 50 miles from the Fukushima accident, thereby possibly contributing to the misinformation that led to the deadly over-evacuation. Connecting SMR and ONT emergency plans to one rem PAGs opens the door to mischief as some may claim that it confirms the need to evacuate out to 40 miles or more.

In 2002 James Lee Witt, former Director of FEMA, was hired by the Governor of NY State to investigate emergency preparedness at Indian Point and Millstone.(10) Mr. Witt utilized a one rem exposure as the standard for emergency planning and response on the basis that the EPA recommended evacuating people if the potential exposure is one rem or higher.(11) Some have said that he advocated people should try to outrun a one rem exposure if a nuclear accident occurred. Mr. Witt was not an opponent to the operation of the Indian Point units but reached conclusions consistent with the state-of-knowledge at that time. We know far more today and should oppose the EPA one rem projection/evacuate guidance that Witt depended on.

There is another insight about PAGs that came out of a unique emergency response study of Indian Point. Entergy, owner of the Indian Point nuclear plants sponsored a study to evaluate the radiation consequences of an assumed successful terrorist attack on Indian Point as described in Appendix B. This unclasified report is available to the NRC and others upon request. One of the parametric analyses in this study was the number of assumed evacuees. Understandably, the larger the evacuating population, the slower the evacuation speed. However, the slower the evacuation speed, the greater the radiation exposure. Evacuating because a one rem PAG might be exceeded may be intended to reduce the radiation exposure of an individual, but when many individuals evacuate, the group can be slowed down and both group and individual exposures might increase. Therefore the application of one rem PAGs can be self-defeating. This is especially true for high population sites like Indian Point. The use of PAGs in emergency planning is an outdated idea and should be discarded. If PAGs are going to continue to be used, they should lead to a sheltering response, not evacuation.

FIGURE A-5 Source Terms versus Distances



a) SST1 b) SST2 c) SST3

Figure 2.6-5. Conditional Probability of Exceeding PAGs Versus Distance for SST1, SST2, and SST3 Source Terms. Assumptions: 1120 MWe PWR, New York City meteorology, and no emergency response.

4.3 The Ranges of Early Health Effects

Exposure to radiation can lead to two groups of health effects, early health effects which would typically manifest themselves within 60 days of exposure and latent health effects that may not be apparent for many years after exposure to radiation. Emergency plans for nuclear power plant accidents are mainly directed at preventing early health effects due to exposure to radiation. However potential long term effects will be reduced by actions taken to prevent early health effects.

Early health effects from exposure to radiation include early fatalities and radiation sicknesses. Early fatalities are treated as being more important than radiation sicknesses as shown by the establishment of nuclear safety goals which are based on early and latent fatalities, not sicknesses.

Various studies of hypothetical nuclear accidents have shown that the range of the early fatality risk is between zero and one mile from the point of release. For radiation sicknesses the range is from zero to two miles from the point of release.As shown in Appendix A, the early response to the Fukushima accident was to evacuate the innermost two miles prior to the release of radioactive material. There was ample time to do this limited evacuation and by doing so the risk of early fatalities or radiation sicknesses was eliminated. The importance of the innermost two miles has been well known for decades and was the basis for describing low population zones.

Even though the expected number of early fatalities and radiation sicknesses is essentially zero, knowledge of these limited ranges is helpful in formulating emergency plans for SMRs and ONTs.

5.0 Avoiding Over-Evacuations

A review of the emergency planning zones NRC website shows a keyhole area in the plume exposure pathway EPZ. This keyhole configuration is comprised of an inner circle two miles in radius and a downwind “tab” area out to five miles, but only one or a few sectors wide (each sector is 22.5 degrees). As discussed before, the basis of the inner two mile circle is that it would encompass radiation-induced early fatalities and sicknesses. For LWRs the best response for this innermost two miles is to evacuate people prior to the release of radioactive material, as was successfully done at Fukushima in spite of a magnitude 9 earthquake and a towering tsunami. Such a priori evacuations could be done in stages with the first stage having a one mile radius. This should be sufficient to eliminate the early fatality risk. If, in the long duration between accident initiation and the beginning of a release of radioactive material into the environment the accident progression is not halted, then the second stage, the evacuation of people in the one mile to two mile ring, should be initiated.

However, the two to five mile downwind “tab” area is troublesome. The important word here is “downwind”. As discussed before, we now know that nuclear accidents have long time periods over which radioactive material might enter the environment. For the two station blackout sequences listed in TABLE A-1, the durations of the release of radioactive material were 22.5 and 26.7 hours. During these very long time periods the wind direction will shift many times. This implies that the “tab” area will shift many times during this prolonged release of radioactive material. If the emergency response in the inner two miles is evacuation it seems likely that evacuation would also be used in the tab area. Should this be the case major potions of the 2 to 5 mile ring in the plume exposure EPZ would be evacuated. Not only would this defeat the purpose of having a “tab” area it would increase the risks associated with over-evacuation. Further, due to the limited ranges of the early fatality and radiation sickness risks, the “tab” would not be effective in reducing these risks.

There is the further concern that during the time period when a “tab” area is being evacuated there is a wind shift. What should emergency responders do then? Should the evacuation of the first “tab” continue or should it stop with a partial evacuation while emphasis is redirected to the new “tab” area? One can expect some shadow evacuation, i.e., people not at radiological risk evacuating nonetheless. If there is confusion about what to do in the tab areas under changing wind conditions this can lead to a decrease in confidence in the authorities conducting the emergency response and a possible increase in the size of the shadow evacuation. Based on what we know today the keyhole design in LWR emergency plans should be replaced by an inner circle two miles in radius. The emergency response beyond these two miles should be downwind sheltering. if the wind direction changes the latest group of people downwind will be alerted to take shelter. Early in the emergency response the public and its elected officials should be informed about how the emergency response would be implemented.

6.0 Other Considerations

6.1 Introduction

There are several other areas that need to be addressed in a modern emergency plan.

6.2 Spent Fuel Pools

If SMR or ONT designs include a spent fuel pool their emergency plans need to make it clear that the emergency plan developed for accidents involving the reactor core encompass accidents originating in the spent fuel pool. The most important isotope that affects the early fatality and radiation sickness risks is iodine-131. However, this radioisotope has a half life of slightly more than 8 days.Once removed from the reactor core and placed into a spent fuel pool is about one month the amount of radioactive iodine would have decreased by a factor of 16 and well below the level of being capable of causing early health effects if released to the environment.

It has been said that former Chairman Jaczko issued his 50 mile evacuation recommendation during the Fukushima accident because of concerns about possible failures of the spent fuel pools. These failures never happened, but even if they had they would not have warranted such a massive evacuation. The spent fuel in the Fukushima spent fuel pools had been there well over a month.

The important isotope in spent fuel pools is cesium-137 which might be a land contamination issue, but it is not an emergency planning issue.

6.3 Hot Spots

Experience from the Fukushima accident shows that the release of radioactive material from a damaged nuclear plant may result in “hot spots”, even beyond the ten mile EPZ. In Japan this eventually led to relocation of people in these hot spots, but quite some time later. (See the Fukushima accident chronology in Appendix A). Emergency plans should include a description of what actions would be taken to deal with hot spots.

6.4 Evacuation Time Estimates and Existing Emergency Plans

Some nuclear power plant sites are requires to make periodic Evacuation Time Estimates. Such analyses estimate how long it would take to totally evacuate the ten mile Plume Exposure Pathway EPZ. The requirement to make such time estimates should be cancelled. These time estimates send the wrong message to the public and their elected officials that a total evacuation of this ten mile area be the kind of emergency response that would be necessary if an accident occurred. This type of massive evacuation is inconsistent with present NRC guidance and increases the non-radiological risks.

There should be a review of all emergency plans at existing nuclear power plant sites. If a plan calls for some kind of a massive evacuation, it should be amended to conform to the guidance given in Section 7 of this report.

6.5 Communicating With the Public and Elected Officials

More needs to be done when it comes to explaining the basis of a nuclear plant’s emergency plan. This would reduce misinformation and dangerous fear mongering. Further, some emergency plans call upon a local elected authority to make the decisions about sheltering and evacuation. This can lead to over-evacuation. Local elected leadership positions, like the County Executive, often change. Some newly elected community leaders can be unaware of the special role they would have to serve if an accident occurred.

The appointment of a local elected leader to be the principal decision-maker should a nuclear accident occur probably has its roots in earlier years when accidents were thought to proceed much more rapidly, thereby not giving NRC or FEMA officials enough time to become part of the decision-making process. Given the present state of knowledge of the long durations between accident initiation and the beginning of a release of radioactive material, the whole subject of “who is in control” needs to be reviewed.

7.0 Recommended Emergency Plan for LWRs

In the event of a possible core melt accident and the announcement of a General Emergency, the innermost one mile around a nuclear power plant should be evacuated prior to the release of radioactive material. Evacuees would be provided with space in a shelter at least two miles from the site boundary. The initiation of this one-mile evacuation should start within a few hours of sounding the emergency alarm, giving plant operators some time to implement mitigative actions and parents some time to pick up their children from nearby schools. Should these mitigative actions not be successful, a second general emergency announcement would be made to evacuate people from the one mile to two mile ring around the site boundary.

Should a radioactive release to the environment start to happen, downwind sheltering should take place starting at two miles and going out to ten miles, using the keyhole angle presently prescribed by the NRC. This is a larger area than the present two to five mile “tab”, but the emergency response in this downwind area is sheltering (does not include evacuation). As the wind shifts, other two to ten mile downwind areas would be advised to take shelter. The dominant emergency protection response for LWRs should be sheltering. This emphasis on sheltering should reduce the probability of over-evacuation. During the course of an accident the public and their elected officials should be kept informed as to what is happening and what the next steps in the emergency response is likely to be.

No change in the size of the ten mile radius EPZ is recommended at this time.

The emergency plan should include the criteria by which people in hot spots, even if they were located outside of the present EPZ, might be relocated and the locations of these shelters should be identified in the emergency plan. Criteria for establishing acceptable dose rates in hot spots that would allow the return of relocated should be established so that they can be returned to their homes as soon as it is safe enough to do this. Acceptable dose rate return criteria should be consistent with return criteria for people that have been evacuated from the innermost two miles. Consideration should be given to non-radiological consequences of relocation and evacuation when establishing these return criteria.

If the accident at the plant site involves the spent fuel pool or any other spent fuel on site, the public and their elected officials should be informed that the emergency response to this type of event is already covered by the emergency plan. With regard to the Ingestion Exposure Pathway EPZ, the same approach proposed for SMRs and ONTs should be utilized.

8.0 Recommended Emergency Plan for SMRs and ONTs

The following recommendations for SMRs and ONTs are meant to apply to such advanced nuclear plants whether they are located on a new site or are placed on a site that has operating LWRs on it. If a General Emergency is declared, it is recommended that people within two miles of the site boundary take shelter prior to the release of any radioactive material into the environment. The actions to be taken if there are hot spots would be the same as those recommended for LWRs and the actions that would be taken to prevent ingestion of contaminated water or foodstuffs would utilize the approach where the need for a specific IPZ (Ingestion Pathway Zone) is unnecessary, provided the capabilities to interdict contaminated food and water do not differ from existing emergency planning regulations.(12)

The two mile sheltering zone for SMRs and ONTs is recommended for a number of reasons. Even though the risks from identified accident sequences is very small, there are always some unknown unknowns. This two mile sheltering zone provides defense-in-depth for unidentified accident sequences. The two mile distance encompasses the early fatality and radiation sicknesses ranges from identified accident sequences.

With the elimination of the 50 mile IPZ and the thought of a one rem TEDE inner boundary based on a PAG approach, the emergency plan for SMRs and ONTs could meet public resistance claiming that there is no substantive emergency plan for these advanced reactors. Such public resistance could greatly delay the acceptance of these advanced designs.

The burden of an all-sheltering area within two miles of the site boundary is not particularly onerous and would go a long way to minimizing the kind of post accident long term sheltering problems that Japan has experienced. If the public perceives that SMRs and ONTs have no effective emergency plan, the response in an accident situation could be chaotic with significant non-radiological consequences.

The two mile radius from the site boundary is consistent with the two mile radius of LWRs but utilizes a sheltering response instead of a staged evacuation response. The two mile distance is consistent with TABLE A-5 for the SST-3 source term for a one rem whole body dose at a conditional probability of 10^{-2}. The SST-3 source term appears to be in the range of expected source terms for SMRs and ONTs.

A primary recommendation in this report is for LWRs to move in the direction of sheltering as the dominant emergency response. With sheltering, non-radiological risks can be reduced. Using a two mile all-sheltering zone for SMRs and ONTs brings these advanced designs into closer alignment with LWRs, especially if the recommendations offered here for LWR emergency plans are implemented.

If PAGs are not to be used in establishing emergency planning requirements for SMRs and ONTs some other basis must be utilized. The proposed two mile sheltering approach accomplishes this.

9.0 Comparison of LWR Emergency Plans to SMR and ONT Emergency Plans

The proposed emergency plans for LWRs, and for SMRs and ONTs have similarities and differences. TABLE A-6 summarizes these similarities and differences in emergency planning.

TABLE A-6 Comparison of LWR and SMR, ONT Emergency Plans

Item	LWRs	SMRs and ONTs
Size of Plume Exposure EPZ, miles.	10	2
Principal emergency response.	Staged evacuation, first 1 mile, then 2 miles. Shelter downwind 2 miles to 10 miles	Shelter inner two miles from site boundary.
Ingestion Exposure EPZ.	Same as SMRs and ONTs	50 mile IPZ replaced by maintaining same food and water detection and decontamination capabilities as presently exist.
Hot Spots.	Develop relocate and return dose rate criteria.	Same as LWRs.
Accidents in Spent Fuel Pools.	Within the scope of the reactor core emergency plan.	Same as LWRs.
Evacuation Time Estimates.	Cancel.	Unnecessary.
Communication with the Public and Elected Officials.	Very necessary.	Very necessary.

10.0 Appendix A - Fukushima Emergency Response Chronology

TABLE A-7 Chronology of the Emergency Responses at Fukushima

Time in year 2011	Distance from site, km	Action
March11@ 14:46	N/A	Magnitude 9 earthquake
March 11@ 15:42	N/A	Units 1, 2, and 3 lose power
March11@ 20:50 and @ 21:23	2, 3	Two pre-emptive evacuations
March 12@ 05:44	10	Compulsory evacuation
March 12@18:25	20	Compulsory evacuation
March 15	20-30	Shelter in home
March 25	20-30	Self evacuation
April 22	Areas with dose rates > 20 mSv/year	Evacuation within a month
June 16	Hot spots with dose rates > 20 mSv/year	Recommended for evacuation (relocation)

11.0 Appendix B - Hypothetical Terrorist Attack on Indian Point

During the September, 2011 terrorist attack on the United States one of the commandeered airplanes flew near the Indian Point site. This prompted many questions about what might have happened if this plane had purposely crashed into Indian Point 2 or 3. In order to get a better understanding of the possible health consequences of a successful terrorist attack on Indian Point, Entergy, owner of the Indian Point power plants, sponsored a unique and highly conservative hypothetical terrorist attack analysis.

In this hypothetical analysis it was first assumed that the terrorists were able to create a three square foot hole in one of the containment buildings. Considering the massive strength of these robust containment buildings this would be very difficult to do. A hole larger than three square feet would not increase the severity of this attack in a meaningful way. It was then conservatively assumed that these terrorists were able to start a core melt sequence in just one half an hour once they entered the Indian Point site. Two core melt sequences were examined. One was a total station blackout and the other a loss of coolant event (pipe break).

Starting with this string of highly unlikely assumptions, two teams of experts were assembled. One expert team specialized in traffic analysis and had completed detailed evacuation time estimates before for the Indian Point site. Some 357 population centroids were used to describe where people would begin their evacuations. Because of the short ranges of the early fatality and radiation sickesses risks, the traffic analysis team greatly increased the number of centroids in their analyses within the innermost four miles from the site. (See FIGURE A-6). These traffic analysts mapped out every street in great detail within a few miles of Indian Point. They accounted for a variety of parameters, such as the number and location of people who had no cars, where people resided, the time distribution of when people begin to evacuate, and the population that would be assumed to evacuate under variety of conditions like summer versus winter, mid-day, evening and weekend evacuation populations, and so forth. In all, some 18 different traffic scenarios were examined where the largest evacuating population would be in the mid-day, mid-week population. This traffic scenario happens about 12% of the time. The traffic analyses experts modeled multiple cohorts of people evacuating slowly in their cars down the streets surrounding Indian Point. Each cohort had travel speeds that depended where they were in the road network, how many cars were on the road, actions taken by evacuees further away from the nuclear site but that could affect the evacuation speed of people closer to the site. Sometimes the evacuation speeds were less than one mile per hour. This extraordinary traffic analysis won a prize from a traffic analysis professional society.

The other expert team specialized in analyzing the amounts, timing, and types of radioactive material that might enter the area surrounding Indian Point for both terrorist scenarios. They used actual meteorological data from Indian Point and shielding factors representative of homes in the Indian Point area for the sheltering scenarios. Using the most sophisticated consequence computer code at that time, they were able to calculate dose rates all along the evacuation paths for different weather conditions. One observation was that only highly concentrated radioactive plumes, the very narrow plumes, might be capable of producing high enough dose rates leading to an early fatality. Such narrow plumes only occur about 5% of the time at Indian Point. The combination of the peak traffic at 12% of the time with the frequency of narrow radioactive plumes at 5% of the time means there is a conditional probability of 0.006, or less than one percent of the time that this highly conservative terrorist could produce the health effects presented in TABLE A-8. This conditional probability just represents these two parameters, narrow plumes combined with peak evacuating populations. A far smaller conditional probability would be calculated if analyses of force-on-force insights were used to estimate the likelihood of terrorists being able to create a huge hole in the containment and overcome security forces so that a core melt sequence could be started in a short time period, like the assumed half hour in this analysis.

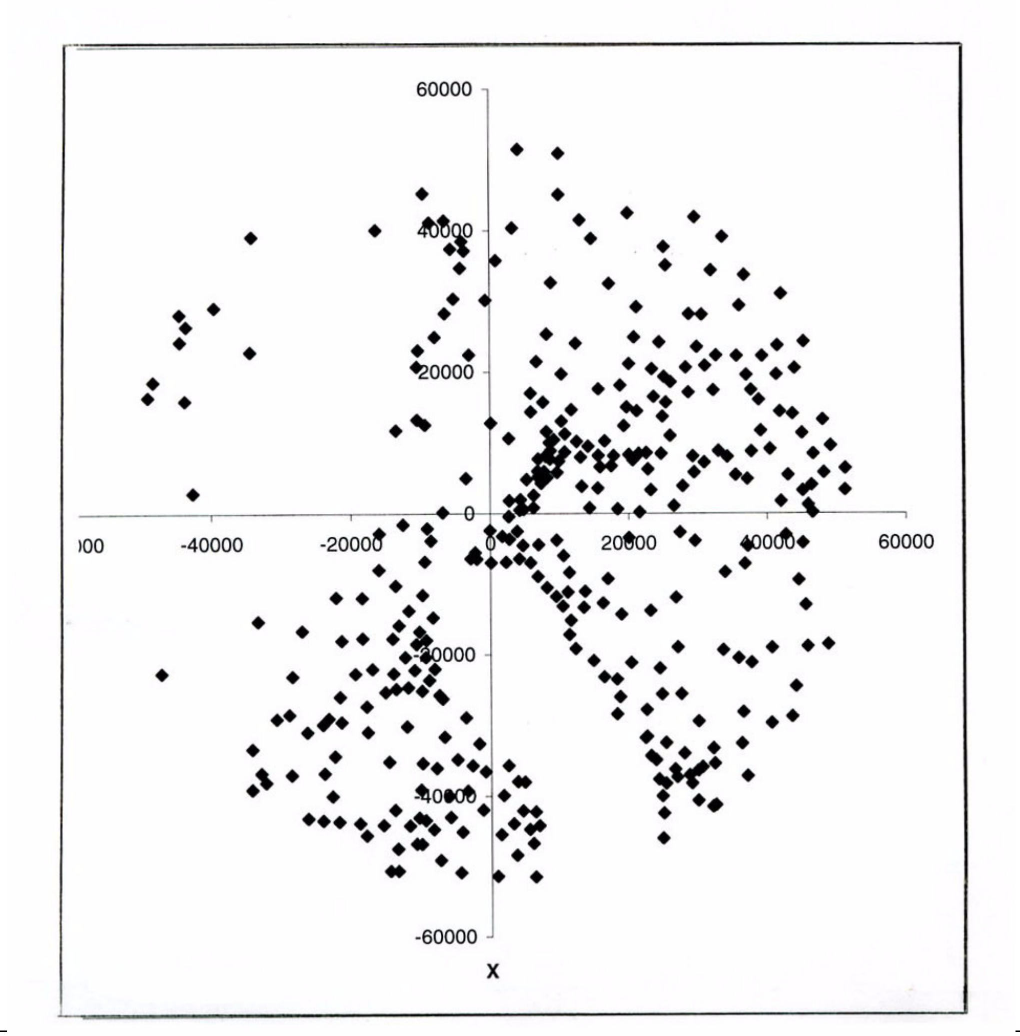
The two teams of experts were brought together and the exposures to radiation were calculated for the various cohorts of evacuees traveling down the local roads. Because of the basically rectangular road system grid around Indian Point evacuees did not move away from Indian Point in a radial manner, the simplistic evacuation model typically used an accident analyses. Rather they either traveled straight ahead or turned right or left as the road system dictated. This meant that evacuees would drive through the plume, more or less in a perpendicular fashion. Even at very slow evacuation speeds the time to cross through the plume was short. The plumes with the highest concentrations of radioactive material are also the most narrow, so the time to drive through them is the shortest. These radiation exposures of the evacuees was then converted into two health effects: early fatalities and radiation sickesses, also called radiation injuries. Long term radiation health effects, like latent fatalities, were estimated using the highly conservative linear non-threshold (LNT) model. The long term consequences, if any, would be too small to be detected. This matches the conclusions about long term effects reached by the World Health Organization in its analysis of the Fukushima accident.

Because it was assumed that a huge hole in the containment was created even before the start of either core melt sequence (station blackout, pipe break) the calculated release fractions were much larger than the SOARCA release fractions shown in TABLE A-1. Specifically, for the station blackout sequence in this hypothetical terrorist analysis had a gallium release fraction of

0.182.The iodine release fraction was 0.274 and the cesium release fraction was 0.180. Many different terrorist scenarios were examined. The worst case scenario was the one with the mid-day, mid-week or maximum evacuation population where 100% of the ten mile EPZ population out to 10 miles, about 370,000 people, plus 30% of the population out to the closest interstate highways were assumed to evacuate. This, the slowest of all evacuations, was combined with the meteorological condition that creates the most concentrated narrow radioactive plumes; together a conditional probability of about 0.006. The calculated number of early fatalities was 5 people, with 203 radiation sicknesses. This scenario can be compared to one where there was a precautionary evacuation of the innermost one mile. In this situation there were zero calculated early fatalities and about 30 cases of radiation sickness.

These highly conservative hypothetical terrorist attack analyses show that even for the nation’s highest population density nuclear site, the expected number of early fatalities from exposure to radiation is at or near zero.

FIGURE A-6 Location of Population Centroids Around Indian Point



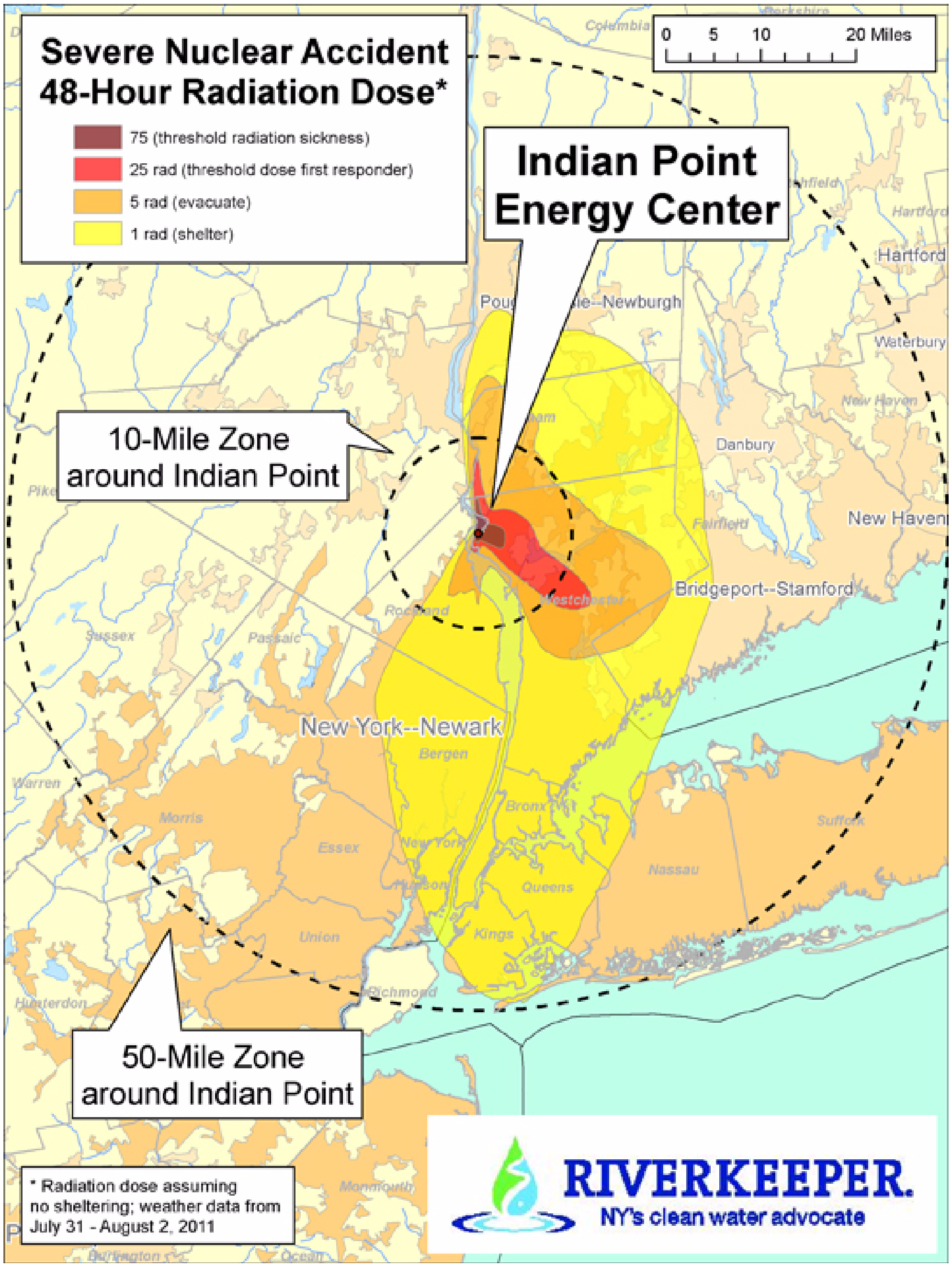
12.0 Appendix C - Riverkeeper/NRDC Accident Analysis of Indian Point

Riverkeeper and the Natural Resources Defense Council have long opposed the operation of the two nuclear power plants, Indian Point 2 and Indian Point 3, in Westchester County, New York. Among the misinformation these groups have put forth is their analysis of the consequences of a hypothetical accident at Indian Point.(13) FIGURE A-6 reproduces the figure Riverkeeper put on its website which claims to show the health consequences from a hypothetical accident at Indian Point. This Riverkeeper/NRDC analysis has major defects. First, this analysis grossly overestimated the amounts of radioactive material that might enter the environment in the accident scenario they chose. The iodine release fraction was 138 times larger than the SOARCA value in TABLE A-1 and was even larger than the old Sandia Siting SST-1 source term, i.e., 0.828 for the NRDC analysis compared to 0.450 for the old Sandia Siting report. The NRDC release fractions for cesium were even worse, 1,278 times larger than the SOARCA number. This huge disparity might be due to the impossible cesium release fraction that NRDC used of 1.278. In the NRDC analysis 27.8% more cesium was released into the atmosphere than had existed in the reactor core.

These erroneous source terms were compounded by an absurd emergency response. The NRDC analysis assumed an emergency response during this fearful event where people would remain out-of-doors for 48 hours. People do not remain out-of-doors for 48 hours even in non-accident conditions.

What is striking about this analysis is that, in spite of greatly overstating the source term and an unrealistic emergency response, zero early fatalities are shown on the Riverkeeper/NRDC figure. Even the claimed radiation sickness area in this Riverkeeper/NRDC analysis only shows up as a small dot near the Indian Point site. Had people in this calculated dot of an area been modeled as people staying indoors or having relocated a half a mile away, this very limited radiation sicknesses area would disappear. Had this NRDC analysis been run with SOARCA source terms the whole area colored in yellow in this NRDC figure would greatly shrink. In order to maximize the impression that a huge area would be affected if there were an accident at Indian Point, NRDC chose a time period during which there were a number of wind shifts. However, in so doing, the NRDC analysis resulted in zero early fatalities. This is consistent with the discussion in Section 3.1.4 of this report.

FIGURE A-7 NRDC Analysis of an Accident at Indian Point



Severe Nuclear Accident 48-Hour Radiation Dose*

🟫 75 (threshold radiation sickness)
🟥 25 rad (threshold dose first responder)
🟧 5 rad (evacuate)
🟨 1 rad (shelter)

Indian Point Energy Center

10-Mile Zone around Indian Point

50-Mile Zone around Indian Point

* Radiation dose assuming no sheltering; weather data from July 31 - August 2, 2011

13.0 End Notes

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3. "State-of-the-Art Reactor Consequence Analyses (SOARCA) Report", NUREG-1935, TABLE 7-1, November, 2012.
4. NUREG/CR -2239,"Technical Guidance for Siting Criteria Development", D.C. Aldrich, et al, Sandia National Laboratories, 1982.
5. "Fukushima and the Indian Point Emergency Plan", Slide 11, Herschel Specter, Advanced Energy Conference, Javits Center, New York City, N.Y., April, 2012.
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7. "Enhanced Emergency Planning", RBR Consultants, September, 2007.
8. Letter to the Commissioners from Margaret M. Doane, Executive Director for Operations, NRC, page 4, SECY-18-0103, October 12, 2018.
9. Figure 2.6-5, NUREG/CR -2239,"Technical Guidance for Siting Criteria Development", D.C. Aldrich, et al, Sandia National Laboratories, 1982.
10. "Review of Emergency Preparedness at Indian Point and Millstone", James Lee Witt Associates, January 10, 2003.
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12. "Draft Environmental Assessment for the Proposed Rule-Emergency Preparedness for Small Modular Reactors and Other New Technologies", page 5.
13. "Nuclear Accident at Indian Point: Consequences and Costs", M. McKinzie and C.Paine, NRDC, October, 2011.