5.6.2 Radionuclide Transport to the Suppression Pool due to SRV Seizure

The response of SRVs to persistent demands for pressure relief and, once core damage begins, to internal heating by high-temperature gases impacts physical behavior within the RPV in multiple ways. The first and obvious way is the impact on RPV pressure. Among the positive features of seizure in an open position is that the reduction in RPV pressure reduces the mechanical load on the head and thereby delays the time to lower head failure. Conversely, flashing of residual water in the lower plenum of the RPV accelerates the oxidation of metallic components within the core, thereby promoting hydrogen generation. This, in turn, results in a measurable increase in containment pressure. These effects are evident in the results presented in Section 5.1.1.

A subtle, but important effect of SRV seizure on the baseline LTSBO accident progression involves the discharge of airborne fission products from the RPV to the containment through the stuck-open SRV. As described in Section 5.1.2, depressurization accompanying a stuck-open SRV sweeps airborne fission products within the RPV to the torus (wetwell), where they are permanently captured in suppression pool water. Characterizing the time at which a cycling SRV would stick in the open position is, therefore, important for calculating the quantity of airborne fission products that are available for transport to the suppression pool.

Unfortunately, the precise time at which a cycling SRV would stick in the open position cannot be predicted with certainty. This is due, in part, to the fact that the mechanisms causing an SRV to stick in the open position span a very wide range[30] (e.g., bent stem, weakened or broken spring, foreign materials, pilot failure, etc.) and susceptibility to failure changes with the time the valve is in service, the number of cycles experienced by the valve and other factors. Failure data collected by the nuclear industry is applied in PRA in the form of a constant failure rate (i.e., probability of failure (to reseat) upon demand). An SRV failure rate is also used in the MELCOR model for Peach Bottom based on component performance data obtained from the plant-specific PRA. While this information provides a means of estimating the probability of failure (to reseat) given a certain number of cycles, it cannot be used to calculate the precise number of cycles or time at which the valve would fail.

A second contributor to the uncertainty in SRV failure is performance when internal environmental conditions greatly exceed the design specifications for the valve. For example, in the late stages of in-vessel oxidation and damage to the core, the temperature gases exiting the core and discharged through the cycling SRV would be well above the valve design temperature of approx. 580K. Gas discharge temperatures greater than 1000K are calculated before core debris begins to relocate into the lower plenum of the RPV. At these temperatures, plastic deformation of the valve stem, disc and springs will prevent the valve from continuing to cycle properly and seizure in an open (or partially-open) position is likely. The MELCOR model of the SRV cannot rigorously calculate the details of valve heat up and material damage. Instead, a simple criterion is used to represent the expectation that the valve would fail (seize open) when the gas discharge temperature greatly exceeds design specifications. In particular, the MELCOR calculations described here assume a cycling SRV sticks open after the valve has opened ten (10)

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30 A summary of SRV failure mechanisms and causes can be found in EPRI TR-105872s, "Safety and Relief Valve Testing and Maintenance Guide," Electric Power Research Institute, August 1996.

times with internal temperatures above 1000K. This criterion is based on engineering judgment and reflects a qualitative expectation that overheating and thermal expansion of valve component will require a sustained internal heat source and mechanical insults, which necessitates multiple open valve cycles.

It is conceivable, although judged less likely, that the cycling SRV could seize in the closed position. If this were to occur, another SRV would take over the function of pressure relief (11 SRVs at staggered set points are installed at Peach Bottom). Cycling and thermal loading of the second SRV would begin anew. Therefore, the effect of the lowest set point SRV failing to open, rather than failing to reclose, is to extend the effective number of cycles and the thermal capacity of the valve beyond one valve. Uncertainties in the conditions for valve failure (seizure) in the open position therefore, tend to be skewed in the direction of later times (more cycles) than earlier time (fewer cycles.)

Finally, it is conceivable that an SRV would not stick in a position that would cause RPV depressurization before an alternative mechanism of depressurization could occur. Continuous cycling of a single SRV draws hot gases from the RPV, through a single main steam line, to the location of the SRV immediately upstream of the inboard MSIV. This flow of hot gases causes the steam line nozzle and steam line piping to increase in temperature. Sustained exposure of these structures to high internal pressure and increasing temperatures might result in material creep and structural failure. This mechanism of RPV depressurization also sweeps airborne fission products to the containment, but in this case the discharge would be to the drywell rather than the wetwell. Discharged gases and fission products would be carried into the suppression pool through open vent pipes, the attenuation of airborne radioactivity in this case is less than the situation in which fission products enter the suppression pool through an SRV tailpipe and T-quencher. The potential for creep rupture of a main steam line nozzle or piping is evaluated in the MELCOR calculations by using a Larson-Miller formulation similar to the one developed for evaluating failure of the hot leg and steam generator U-tubes in the Surry PWR analysis. Geometry specific to the Peach Bottom main steam line was used in this calculation and a non-dimensional "cumulative damage index" is used to indicate when structural failure could occur. Results of the baseline LTSBO calculation described in Section 5.1.1 suggest conditions amenable to main steam line creep rupture occur within minutes of the time SRV seizure due to damage from thermal effects was calculated. Therefore, the assessment of uncertainties in radionuclide transport to the suppression pool also considered this mechanism of RPV depressurization.

The impacts of alternative modeling assumptions regarding each of the mechanisms of RPV depressurization described above were examined in several sensitivity calculations. In particular, the following alternative cases were considered:

a) <u>Early stuck-open SRV</u>: The lead SRV sticks in the open position in the baseline LTSBO calculation due to damage caused by cycling with internal gas temperatures above 1000K. When the criterion for this failure mechanism is reached, the valve had experienced a total of nearly 500 cycles as indicated in Figure 48. Stochastic failure of the valve did not occur earlier because the confidence level for failure (to reclose) had not yet reached the value of 90% assumed in the baseline calculations. As shown in the figure, however, confidence in failure was just under the stochastic numerical threshold. At a failure rate of 1.3E-3 per demand, and after accumulating a large number of cycles, confidence that the valve would eventually fail to reclose accumulates slowly[31]. Therefore, a modest decrease in the assumed probability for failure results in a significant reduction in the time at which the valve might stick open. A sensitivity calculation was performed to evaluate changes in accident progression and fission product transport to the suppression pool that would result if the lead SRV stuck in the open position at an earlier time. For convenience, it was assumed the valve failed when reactor water level reached the top of active fuel which occurred at 9.2 hours. This ensured full RPV depressurization before significant core damage and fission product release occurred. As indicated in the figure below, the cumulative probability of failure (to reclose) at 9.2 hours is approximately 0.72.

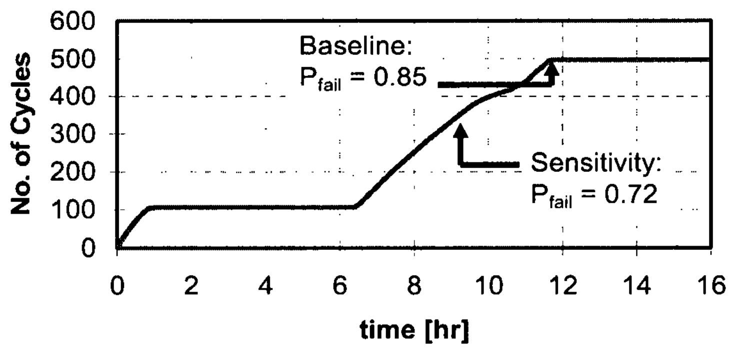

Figure 48 Number of SRV Cycles as a Function of Time (LTSBO)

b) Delayed seizure of the SRV: It is conceivable, although unlikely, that the lead SRV could endure the number of cycles calculated in the baseline calculation without failure. If that occurred, heating of main steam line piping could result in creep rupture and RPV depressurization into the drywell. This possibility is examined in a second sensitivity calculation. Rupture of the main steam line is assumed to occur when the cumulative creep damage index reaches a value of unity. Pipe failure is further assumed to create an opening in the main steam line equivalent to the full diameter of the pipe[32].

c) SRV seizure with a partial-open area: The baseline LTSBO calculation and both of the sensitivity calculations described above assumed the lead SRV sticks in a full-open position. The third sensitivity calculation examined the effects of valve seizure in an intermediate position – one in which the effective open area was one-half the full-open area. The criteria for failure were identical to the baseline calculation.

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31 Confidence in failure is not a linear function of the number of valve cycles. The likelihood of failure increases more rapidly for the first hundred cycles than for cycles after several hundred without a failure.

32 Note: A side calculation was performed to determine whether results were sensitive the size of the opening. Nearly identical results were obtained for any size greater than one-half the area of a single main steam line pipe.

Figure 49 and Figure 50 compare key signatures of the thermal-hydraulic response of the RCS from the sensitivity calculations to the response from the baseline LTSBO calculation. In each case, a stuck-open SRV or pipe rupture initiates a depressurization of the RPV. The smaller flow area associated with the case assuming a partially-open valve results in a slightly slower depressurization rate and an elevated post-blowdown pressure than the other cases, whereas the large area of the ruptured steam line causes the fastest depresurization. The rate at which coolant is discharged from the RPV (reflected as a continuous decrease in reactor water level shown in Figure 50) is also similar among the different cases. However, the sensitivity case with early SRV failure results in core uncover at a much earlier time than the other cases. This is a result of coolant flashing and discharge through the SRV when it sticks in the open position, which is assumed to occur when RPV water level reaches the top of active fuel. If RPV depressurization accompanying valve seizure were complete significantly before the time RPV water level reached TAF, the rate at which RPV water level decreased below TAF would more closely resemble the trends shown for the other cases.

Nevertheless, the early and rapid loss of coolant from the core in the case with early SRV seizure causes the onset of clad oxidation, fission product release and core material relocation move forward by approximately two hours in comparison to the baseline and other sensitivity cases. Conversely, the times of lower head failure and containment failure are slightly delayed in this case (relative to each of the other cases) due to the larger amount of water in the RPV lower plenum available for debris cooling after material relocation into the lower head.

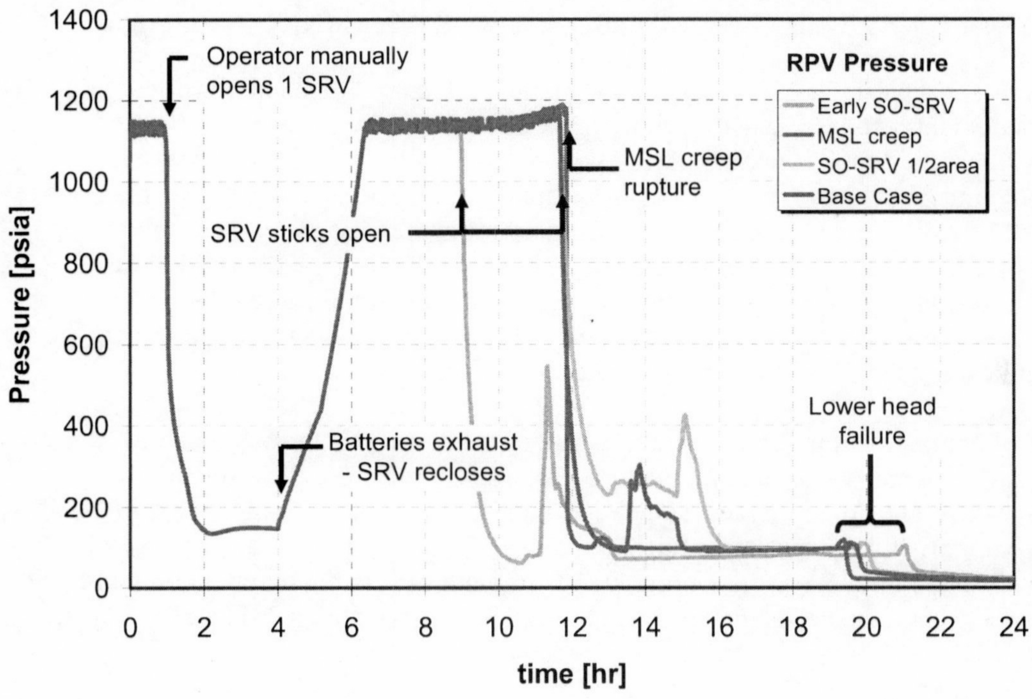

Figure 49 RPV Pressure: LTSBO versus SRV Sensitivity Calculations

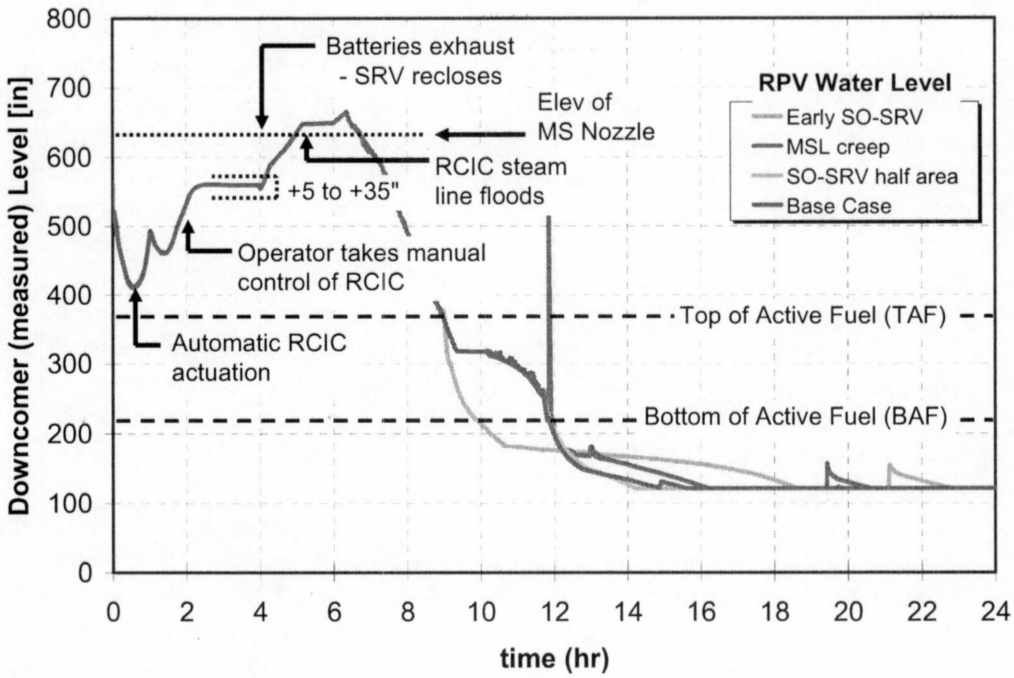

Figure 50 RPV Water Level: LTSBO versus SRV Sensitivity Calculations

The differences in thermal-hydraulic behavior within the RCS summarized above affect the calculated containment response. As shown in Figure 51, each of the cases in which RPV depressurization results from a stuck-open SRV generates a similar containment pressure signature. Containment pressure increases in proportion to the amount of hydrogen generated by the oxidation of Zircaloy cladding in the core[33]. A more rapid increase in pressure follows reactor vessel breach due to the discharge of residual hydrogen from the RPV and because molten core debris released to the drywell floor heats the drywell atmosphere. Soon after vessel breach however (within 15 minutes), core debris melts through the drywell shell, allowing the containment atmosphere to depressurize into the reactor building.

The similarity of containment pressure signatures among the cases with a stuck-open SRV is not shared by the case in which main steam line creep rupture occurs before SRV seizure. It generates a very different signature (also shown in Figure 51.) The rapid blowdown of the RPV accompanying rupture of the main steam line results in a rapid discharge of steam and hydrogen to the drywell. This, in turn, causes in a prompt and large increase in containment pressure. The peak containment pressure exceeds the failure pressure for the drywell head flange by a large

[33] The containment pressure observed in the case with an early stuck-open SRV is generally lower than the baseline case and the case with a partially-open SRV, but has a qualitatively similar trend. The lower pressure in this case is caused by a reduced level of in-vessel hydrogen generation prior to RPV lower head failure (50% clad oxidized versus 75% in the baseline calculation). This, in turn, is due to reduced availability of steam to the core during in-vessel damage progression, as reflected in the rapid decrease in RPV water level shown in Figure 501.

margin and leakage across the head flange seal is sustained for several hours before depressurization occurs as a result of drywell shell melt-through. The relatively small opening area in the drywell head flange (refer to Section 4.5) is not sufficient to relieve the internal pressure generated by the large quantity of non-condensible gas (hydrogen) released to the containment. As a result, pressure remains at or above 80 psig for several hours.

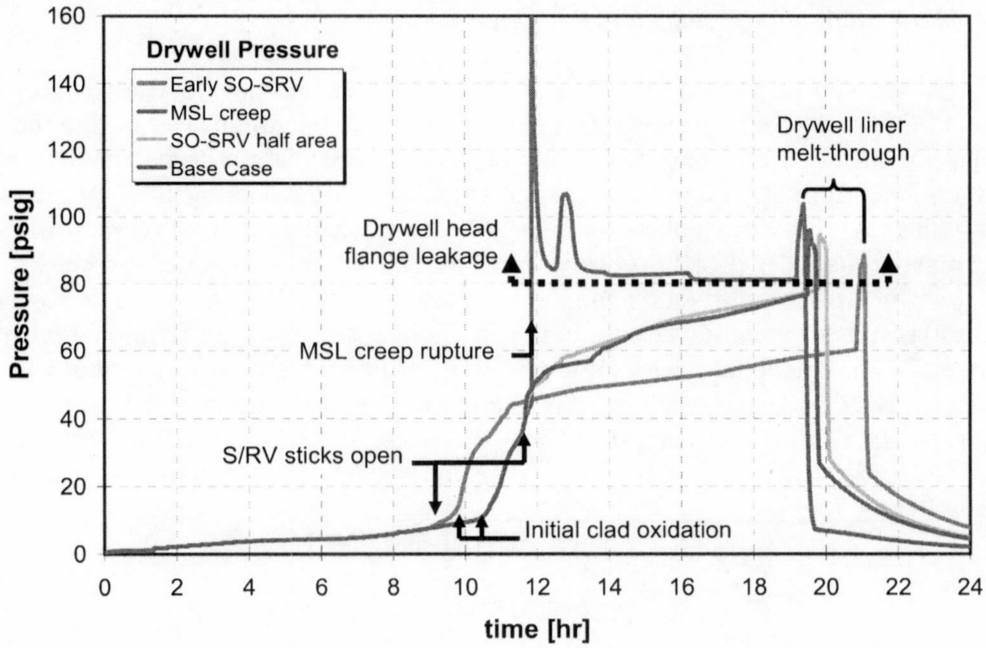

Figure 51 Containment Pressure: LTSBO versus SRV Sensitivity Calculations

These differences in the thermal-hydraulic response of the RCS and containment have a noticeable effect on the magnitude of the radionuclide source term. Figure 52 compares the total quantity of radioactive iodine released to the environment for each of the sensitivity cases to the result for the base case calculation. Figure 53 provides the same information for cesium.

Differences in RCS and containment thermal-hydraulic behavior among the sensitivity cases (summarized above) impact the magnitude and timing of the radionuclide source term for the LTSBO scenario. Relatively small changes in the criteria used to determine the timing and mechanism of RPV depressurization result in significant changes to the pathway and driving forces for transport of radionuclides from the RPV to the containment and from the containment to the environment. Early (stochastic) failure of a cycling SRV, for example, shifts the time at RPV depressurization occurs and therefore affects the sweep out of volatile fission products to the suppression pool. Similarly, creep rupture of the main steam line shifts the transport pathway from the RPV to the containment away from the SRV tailpipe and submerged T-quenchers and instead discharges volatile radionuclides to the drywell. The airborne drywell inventory is subsequently swept into the suppression pool via the downcomer, but the aerosol scrubbing through this pathway is not as efficient as a release through the T-quenchers.

These effects are evident in Figure 54 and Figure 55, which compare temporal changes in the spatial distribution of iodine and cesium from the sensitivity calculations to the baseline LTSBO calculation. Early seizure of an SRV (relative to time reflected in the baseline case) increases the fractional transport of airborne iodine (CsI) to the suppression pool, but reduces the transport of (lower volatility) cesium molybdate. Creep rupture of the main steam line, in contrast reduces the fractional retention of both species in the suppression pool.

Changes in the spatial distribution of fission products affect the ultimate release to the environment. Figure 52 compares the total quantity of radioactive iodine released to the environment for each of the sensitivity cases to the result for the base case calculation. Figure 53 provides the same information for cesium. Each of the alternate modeling assumptions examined in the sensitivity calculations has a measureable effect on the environmental source term. The most pronounced effect is observed in the case with main steam line creep rupture. The early (over-pressure) failure of containment, followed by drywell shell melt through (after vessel breach) results in an earlier release to the environment and a larger fractional release of all volatile species. The fractional release of iodine and cesium increased by a factor of five and three, respectively. Conversely, the environmental release of both species decreased by a similar amount in the case with early seizure of an SRV.

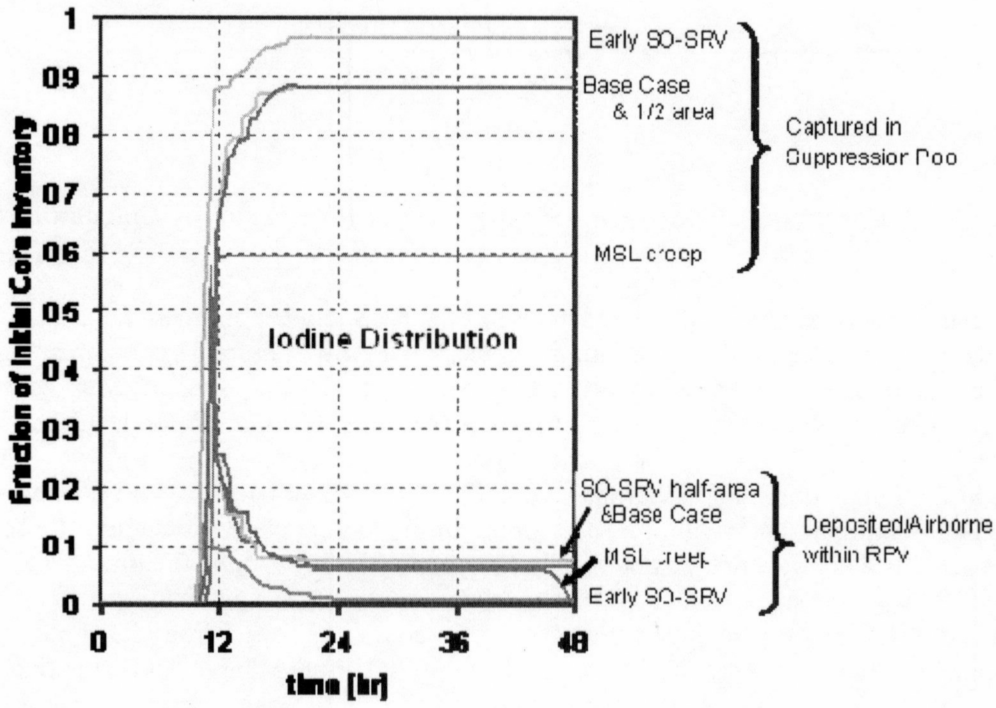

Figure 52 Spatial Distributions of Iodine: LTSBO versus SRV Sensitivity Calculations

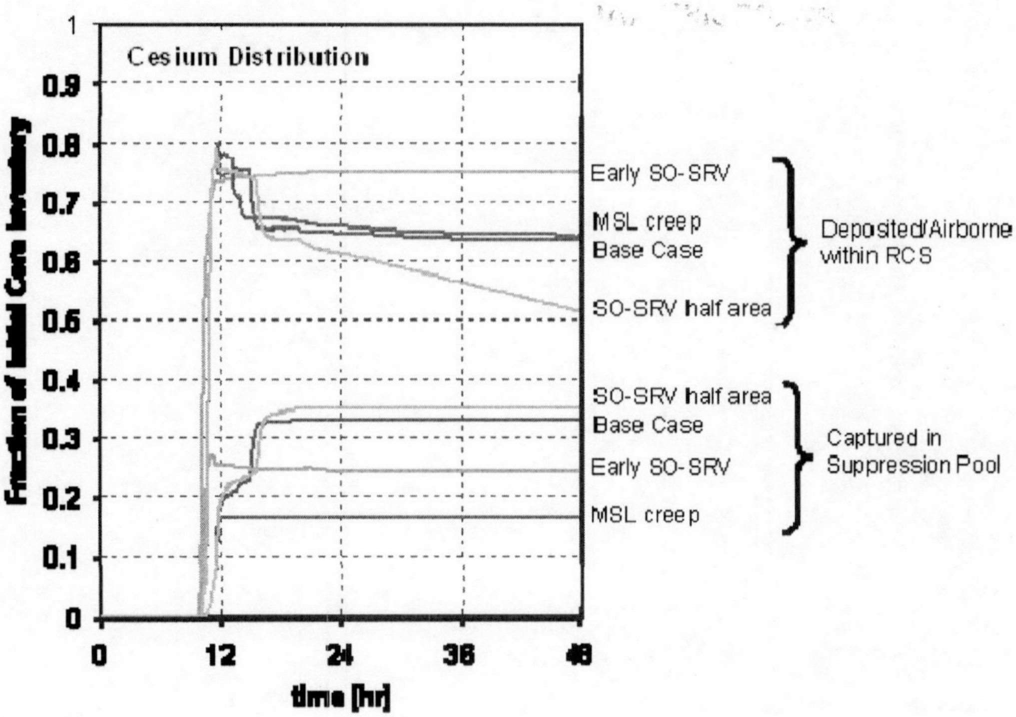

Figure 53 Spatial Distribution of Cesium: LTSBO versus SRV Sensitivity Calculations

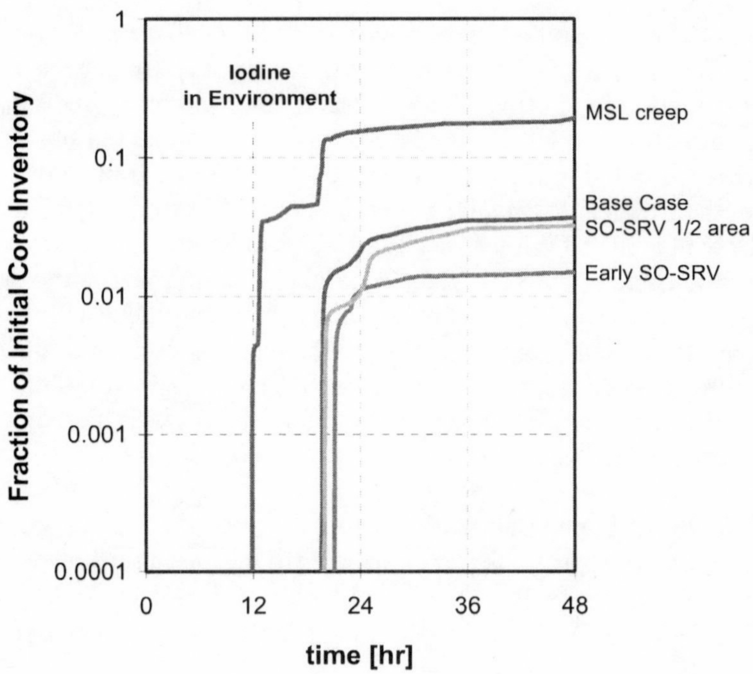

Figure 54 Iodine Release to Environment: LTSBO versus SRV Sensitivity Calculations

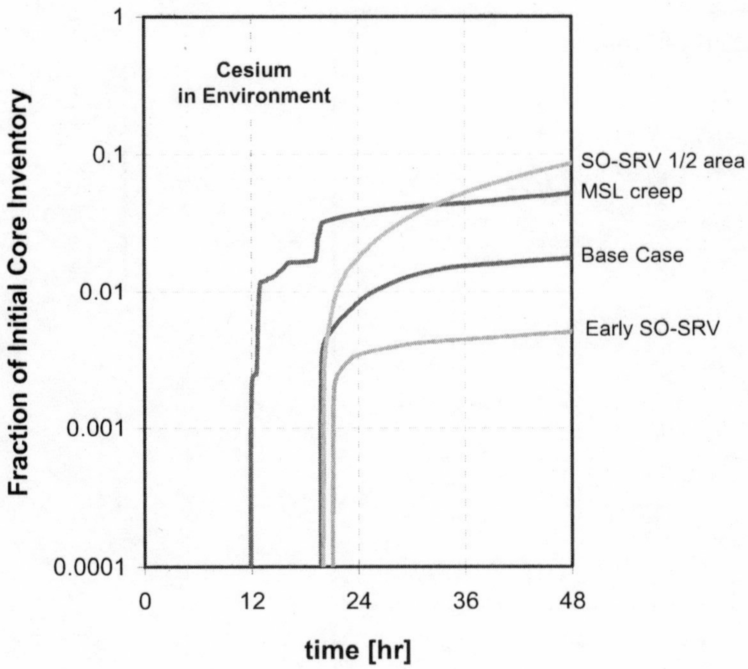

Figure 55 Cesium Release to Environment: LTSBO versus SRV Sensitivity Calculations

5.6.3 Atmosphere mixing in the drywell

The hydrodynamic model of the containment cannot explicitly calculate buoyancy-driven natural circulation flow patterns. The spatial representation of the drywell, in particular, is a simple series of three vertically-stacked control volumes, each connected by a single flow path. The possibility of rising hot gases and descending cooler gases within this region of the containment cannot be rigorously represented in the current MELCOR modeling framework. The absence of natural circulation in the MELCOR calculations results in an inverted, stratified temperature profile within the drywell after RPV lower head failure as indicated in Figure 56. This configuration is possible if the buoyancy-driven natural circulation within the drywell is inhibited by flow resistance associated with piping and other equipment within the drywell[34]. Further, depressurization of the containment through the opening created in the drywell shell near the elevation of the drywell floor (base of region 'D' Figure 56) would preferentially discharge high-temperature atmosphere near the bottom of the drywell, perhaps supporting a high-temperature region near the drywell floor.

On the other hand, the vertical temperature differences between the top and bottom of the drywell reflected in Figure 56 represents a very strong driving force for upward flow. If a return (downward) flow path for cooler air from the top of the drywell is established, the resulting flow

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34 Unlike the idealized image shown on the right-hand side of Figure 566, a large fraction of the internal free volume and horizontal cross-sectional area of the drywell is displaced by piping, valves, electrical control and instrument cabling and several layers of work platform grating.

pattern would enhance mixing of the drywell atmosphere prior to being discharged to the reactor building. Analytical models for properly calculating buoyancy-driven natural circulation flow patterns with a large volume, such as a BWR Mark I drywell, are not available within MELCOR. However, the effects of atmosphere mixing can be examined by imposing a flow path configuration in the MELCOR model that encourages flow among the three vertically-stacked control volumes representing the main body of the drywell atmosphere. This configuration involves replacing the single flow path connecting adjacent control volumes with two parallel flow paths and defining the endpoints of parallel flow paths to be slightly asymmetric.

This adjustment to the baseline modeling approach was made in a sensitivity calculation. The result was a nearly continuous circulation velocity within the drywell of approximately 0.5 m/s and, as shown in Figure 57, a merging of atmosphere temperatures in the control volumes representing the main body of the drywell. The atmosphere temperature within the reactor pedestal (region 'D' in the figure) is not significantly affected by this modeling adjustment.

The impact of drywell atmosphere mixing on the radiological source term to the environment is small, however, as indicated in Figure 58. The final release fractions of iodine is nearly the same in the baseline and sensitivity calculation (3.7% vs 3.2%) and the long-term cesium release fraction increases by a small amount in the sensitivity calculation (from 1.8% to 2.4%). As noted in Sections 5.1.2 and 5.6.1, changes in containment behavior after vessel breach have a more pronounced effect on the long-term releases of cesium than iodine due to differences in volatility associated with their chemical forms.

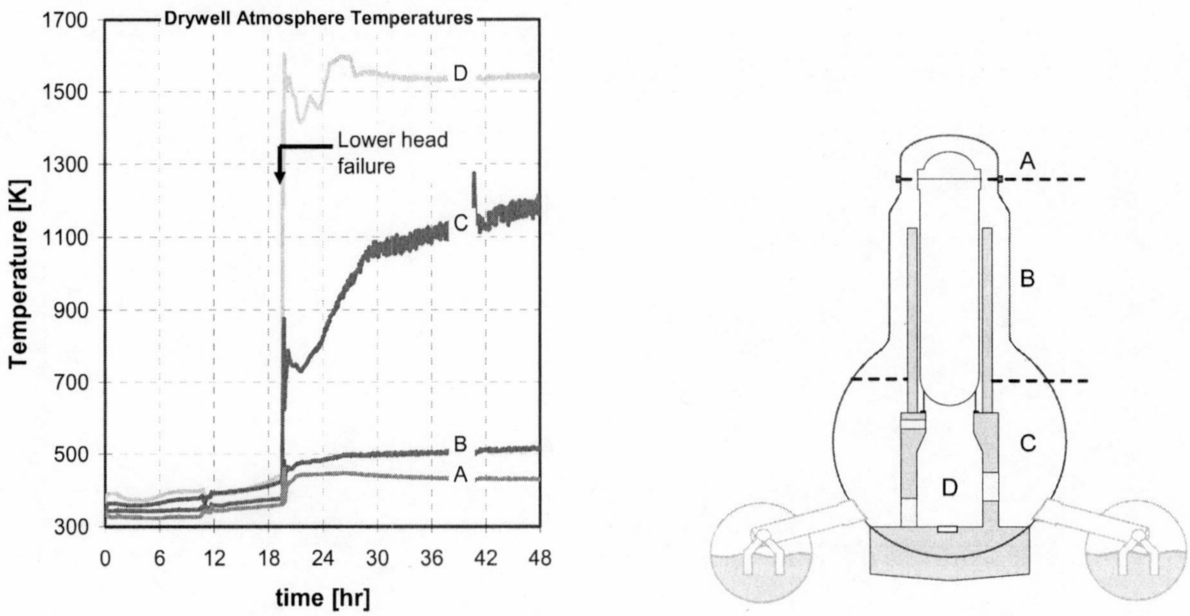
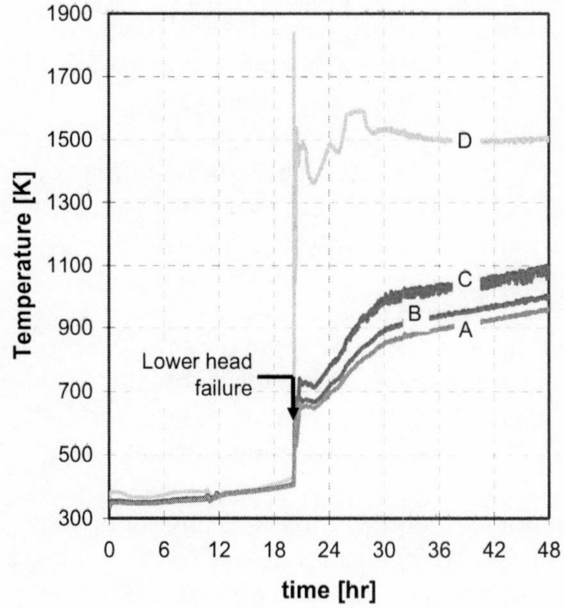


Figure 56 Drywell Atmosphere Temperatures in the Baseline LTSBO Calculation



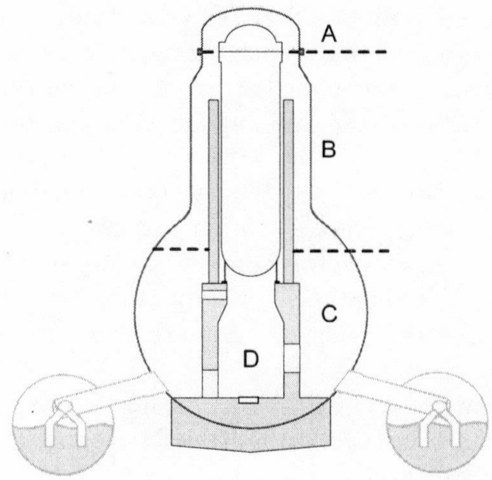


Figure 57 Drywell Atmosphere Temperatures with Imposed Drywell Circulation

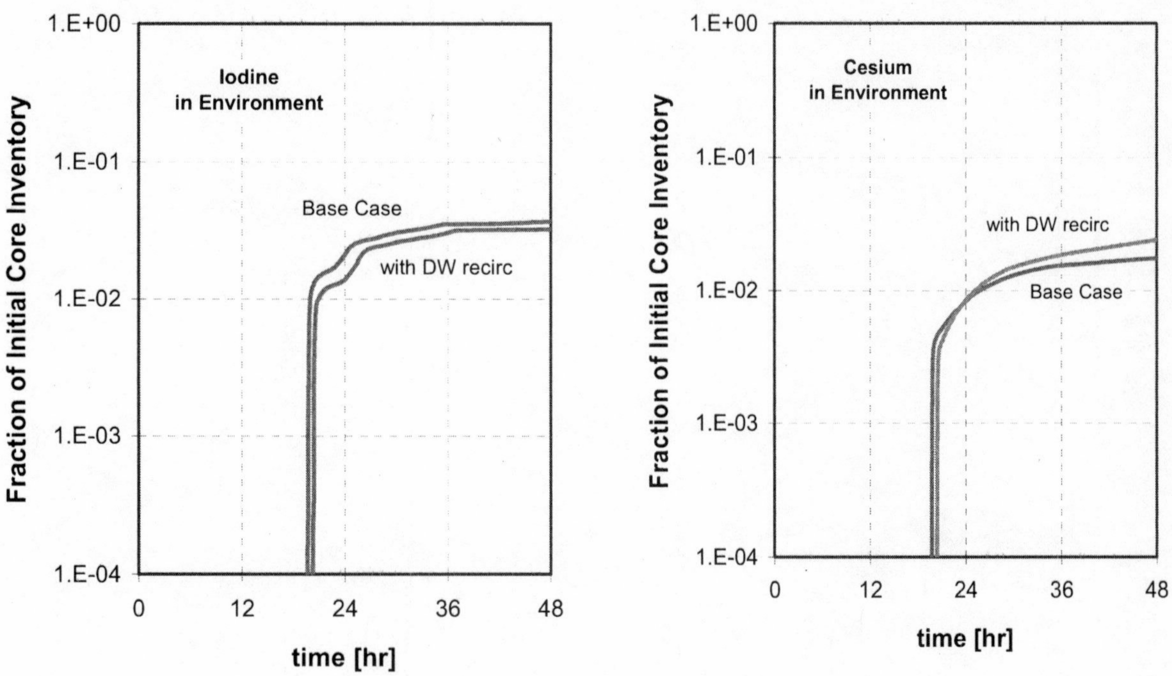


Figure 58 Effect of Modeling Circulation Flow within the Drywell on Iodine and Cesium Release to the Environment

6.0 EMERGENCY RESPONSE

Advancements in consequence modeling provide an opportunity to integrate realism in the implementation of protective action decisions applied for discrete population segments. To best utilize these advancements, detailed information was obtained from local sources and offsite response organizations (OROs). Through a user interface added to the consequence model, this information was input to account for differences in the implementation of protective actions by various population segments. These advancements are significant because they now allow the modeling of response activities, timing of decisions, and implementation of protective actions across different population segments.

Emergency response programs for nuclear power plants (NPPs) are designed to protect public health and safety in the event of a radiological accident. These emergency response programs are developed, tested, and evaluated and are in place as defense in depth to respond in the unlikely event of an accident. To support a state-of-the art approach and integrate realism in the analyses, the modeling of the emergency response was based on the site-specific emergency planning documentation and on research of public response to non-nuclear emergencies. The information developed in this Emergency Response section was used to support the MACCS2 consequence analyses for the accident scenarios. For each accident scenario, evacuation of the plume exposure pathway emergency planning zone (EPZ) was assessed along with consideration of a shadow evacuation to a distance of 20 miles from the plant. In addition, a sensitivity analysis was completed for one accident scenario which assessed evacuation to distances of 16 miles and 20 miles from the plant. Figure 59 identifies the location of the Peach Bottom plant and radial distances of 10 and 20 miles from the plant. Also, for each scenario, members of the public are relocated from any area where doses exceed established criteria.

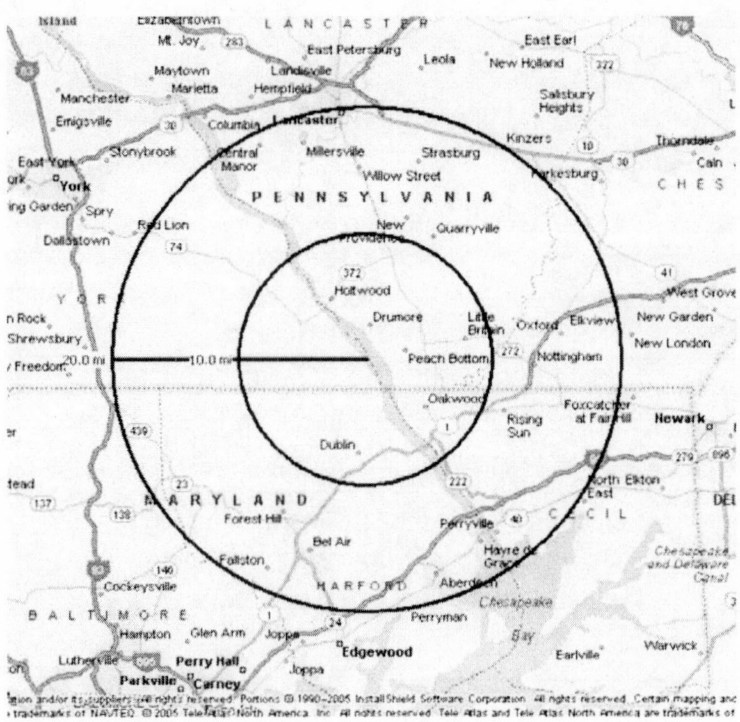


Figure 59 Peach Bottom 10 and 20 Mile Analysis Areas

As required by 10 CFR 50, OROs develop emergency response plans for implementation in the event of an NPP accident. These plans are regularly drilled and inspected biennially through a demonstration exercise performed in conjunction with the licensee. In biennial exercises, ORO personnel demonstrate timely decision making and the ability to implement public protective actions. Emergency plans escalate response activities in accordance with a classification scheme based on emergency action levels (EALs). Preplanned actions are implemented at each classification level including Unusual Event, Alert, Site Area Emergency (SAE), and General Emergency (GE). Public protective actions are required at the GE level, but ORO plans commonly include precautionary protective actions at the SAE level and sometimes at an Alert. For example, at Peach Bottom sirens are sounded at the SAE to inform the public that an incident has occurred and they should monitor Emergency Alert System stations for updated information.

The plume exposure pathway EPZ is identified in NUREG-0654/FEMA-REP-1, Rev. 1 [18] as the area around an NPP of about 10 miles. Within the EPZ, detailed emergency plans are in place to reduce the risk of public health consequences in the unlikely event of an accident. Emergency planning within the EPZ provides a substantial basis for expansion of response efforts should it be necessary [21]. ORO personnel have repeatedly demonstrated the ability to implement protective actions within the EPZ during inspected biennial exercises and modeling of expected protective action response described in this section is consistent with exercise performance data. The modeling includes the State of Pennsylvania position that if an evacuation is ordred, it will include the entire EPZ. This poition differs from other states where evacuation of downwind areas would be implemented rather than the full EPZ. For the analyses herein, a full evacuation was modeled assuming that the State of Maryland OROs would agree with the Pennsylvania protective action decisions. Analyses were conducted for accident scenarios identified in Table 9.

Table 9 Scenarios Assessed for Emergency Response

#	Scenario
6.3.1	LTSBO Unmitigates
6.3.2	STSBO – with RCIC Blackstart
6.3.3	STSBO – without RCIC Blackstart
6.4.1	Sensitivity 1 for the STSBO without RCIC Blackstart and Evacuation to 16 Miles
6.4.2	Sensitivity 2 STSBO (without RCIC Blackstart) and evacuation to 20 miles
6.4.3	Sensitivity 3 for the STSBO without RCIC Blackstart with a Delay in Implementation of protective Actions
6.5.6	Seismic Analysis - STSBO without RCIC Blackstart

6.1 Population Attributes

SOARCA modeled the population near the Peach Bottom plant as several cohorts. A cohort is any population group that mobilizes or moves differently from other population groups. Modeling includes members of the public who evacuate early, evacuate late, and those who refuse to evacuate. The consequence model does not constrain the number of cohorts, but there is no benefit to defining an excessive number of cohorts with little difference in characteristics. The following cohorts were established for SOARCA analyses:

Cohort 1: 0 to 10 Public. This cohort includes the public residing within the EPZ.

Cohort 2: 10 to 20 Shadow. This cohort includes the shadow evacuation from the 10 to 20 mile area beyond the EPZ. A shadow evacuation occurs when members of the public evacuate from areas that are not under official evacuation orders and generally begin when a large scale evacuation is ordered [19]. A shadow evacuation of 20 percent of the public was assumed based on the quantitative assessment of shadow evacuations completed by the NRC [30].

Cohort 3: 0 to 10 Schools and 0 to 10 Shadow. This cohort includes elementary, middle, and high school populations within the EPZ. Schools receive early and direct warning from OROs and have response plans in place to support busing of students out of the EPZ. A shadow evacuation from within the EPZ is included because sirens are sounded at SAE. This is expected to stimulate an evacuation of some of the residents from within the EPZ beginning about the same time as the evacuation of the schools.

Cohort 4: 0 to 10 Special Facilities. The Special Facilities population includes residents of hospitals, nursing homes, assisted living communities and prisons. Special facility residents are assumed to reside in robust facilities such as hospitals, nursing homes, or similar structures that provide additional shielding. Shielding factors for this population group consider this fact.

Cohort 5: 0 to 10 Tail. The 0 to 10 Tail is defined as the last 10 percent of the public to evacuate from the 10 mile EPZ. The approach to modeling the Tail is an analysis simplification to support inclusion of this population group. In reality, this population group is performing multiple activities prior to the evacuation of this cohort. The Tail takes longer to evacuate for many reasons such as the need to return home from work to evacuate with the family, pick up children, shut down farming or manufacturing operations or perform other actions prior to evacuating. It also includes those who may miss the initial notification.

Cohort 6: Non-evacuating public. This cohort group represents a portion of the public from 0 to 10 miles who may refuse to evacuate and is assumed to be 0.5 percent of the population. Research of large scale evacuations has shown that a small percent of the public refuses to evacuate [19] and this cohort accounts for this potential group. It is important to note that emergency planning is in place to support evacuation of 100 percent of the public.

6.1.1 Population Distribution

The total Peach Bottom population for the 0 to 20 mile area was obtained from the U.S. Census Bureau from the 2000 census. That population was projected to 2005 using a multiplier of 1.0533 also obtained from the Census Bureau. The Peach Bottom ETE presents a detailed estimate of the population cohorts within the 0 to 10 mile region. The ETE population values were used got the 0-10 mile cohorts and were not projected to 2005 values. Table 10 summarizes the populations in each cohort used for the SOARCA analyses of the Peach Bottom site.

Table 10 Peach Bottom Cohort Population Values

Cohort	Description	Population
1	Public (0 to 10)	39,438
2	Shadow (10 to 20)	77,096
3	Schools (0 to 10) and Shadow (0 to 10)	26,413
4	Special Facilities (0 to 10)	400
5	Tail (0 to 10)	4,382
6	Non-evacuating public (0 to 10)	355

6.1.2 Evacuation Time Estimates

As provided in 10 CFR 50.47 Appendix E, each licensee is required to estimate the time to evacuate the EPZ. Appendix 4 of NUREG-0654/FEMA-REP-1, Rev. 1 [18] provides information on the requirements of ETEs, and NUREG/CR-6863 [21] provides detailed guidance on development of ETEs. A typical ETE includes many evacuation scenarios to help identify the combination of events for normal and off-normal conditions[35] and provides emergency planners with estimates of the time to evacuate the EPZ under varying conditions [21]. The ETE study provides information regarding population characteristics, mobilization of the public, special facilities, transportation infrastructure and other information used to estimate the time to evacuate the EPZ.

The SOARCA project used a normal weather winter weekday scenario that includes schools in session. This scenario was selected because it presents several challenges to timely protective action implementation, including evacuating while residents are at work and mobilizing buses to evacuate children at school.

In calculating evacuation time estimates for the SOARCA project, the most recent ETE available from the licensee was used to establish evacuation speeds and delay times within the EPZ [28]. The following ETEs, rounded to the nearest quarter hour, were used in the development of

[35] The term "off-normal condition" includes unique weather, sporting or entertainment events or other occurrences that would significantly disrupt normal population movements.

evacuation speeds within the EPZ. These ETEs correspond to the normal weather winter weekday scenario.

- 100 percent evacuation: 5 hours and 15 minutes and
- 90 percent evacuation: 4 hours and 15 minutes.

These values were used to develop the speeds for the cohorts used in the analysis. The summer weekend ETE and the winter weeknight ETE were also provided in the Peach Bottom study [28] and were considered for use; however, the ETEs for these two scenarios were each approximately 4 hours and 45 minutes for the 100 percent evacuation. The winter weekday scenario was therefore selected because with an ETE of 5 hours and 15 minutes it can be considered the bounding ETE case for the analysis since it provides the longer evacuation time.

For the evacuation scenarios, a speed is input into the consequence model. The evacuation speed is developed from the ETE and is primarily influenced by population density and roadway capacity. When using ETE information, it is important to understand the components of the time estimate. The ETE includes mobilization activities that the public undertakes upon receiving the initial notification of the incident [19][21]. These actions include receiving the warning, verifying information, gathering children, pets, belongings, etc., packing, securing the home, and other evacuation preparations. Thus, a 5 hour ETE does not indicate that all of the vehicles are en route for 5 hours but is the end of a 5 hour period in which the public mobilizes and evacuates the area. MACCS2 cohorts are modeled to begin evacuationg at a specific time after notification. This requires the speed be developed as a single linear value of distance divided by time (the ETE). This distance over ETE ratio provides a slower average speed than would be expected in an evacuation and adds some conservatism to the analysis.

The time to complete an evacuation can be represented as a curve that is relatively steep at the beginning and tends to flatten as the last members of the public exit the area. Through review of more than 20 existing ETE studies, the point at which the curve tends to flatten occurs where approximately 90 percent of the population has evacuated. This is consistent with research that has shown that a small portion of the population takes a longer time to evacuate than the rest of the general public and is the last to leave the evacuation area [19]. This last 10 percent of the population is identified as the evacuation tail. For the analyses in this study, the 90 percent ETE value was used to derive evacuation speeds and the 10 percent tail was analyzed as a separate cohort.

6.2 WinMACCS

WinMACCS is a user interface fir the MACCS2 code and was used to generate input for MACCS2 model runs. WinMACCS has the ability to integrate the information described above into the consequence analysis. The evacuation area was mapped onto the WinMACCS radial sector grid network. The roadway network was reviewed against site-specific evacuation plans to determine likely evacuation direction in each grid element. The results of the ETE were reviewed to determine localized areas of congestion as well as areas where no congestion occurs. Speed adjustment factors were applied at the grid element level to speed up vehicles in the rural uncongested areas and to slow vehicles in more urban settings where the modeling indicates that speeds are lower than the average values used in the analyses.

6.2.1 Hotspot and Normal Relocation and Habitability

In the unlikely case of a severe accident and radiological release, the population outside the EPZ would be relocated from areas where the dose exceeds protective action criteria. OROs would base this determination on dose projections using state, utility, and Federal agency computer models as well as measurements taken in the field. Hotspot relocation and normal relocation models are included in the MACCS2 code to reflect this activity and include dose from cloudshine, groundshine, direct inhalation, and resuspension inhalation. Within the MACCS2 calculation, individuals that would be relocated because their projected total committed dose from these pathways exceeds the protective action criteria are prevented from receiving any additional dose during the emergency phase. This reflects the impact of the relocation of these individuals that would take place in the event of an actual radiological release. This relocation dose criterion is applied after plume arrival at the affected area and is also applied to the non-evacuating cohort within the EPZ even though this small fraction of the population does not comply with previous evacuation orders. It is assumed these individuals will evacuate when they understand a release has in fact occurred and they are informed they are located in high dose areas.

For hotspot relocation, individuals are relocated 12 hours after plume arrival if the total lifetime dose commitment for the weeklong emergency phase exceeds 0.05 Sv (5 rem). For normal relocation, such individuals are relocated 24 hours after plume arrival if the total lifetime dose commitment exceeds 0.005 Sv (0.5 rem). The relocation times of 12 hours for hotspot and 24 hours for normal relocation were established based on review of the emergency response time lines, which suggest that OROs would not likely be available earlier to assist with relocation because of higher priority tasks in the evacuation area.

Site-specific values are used to determine long-term habitability. Most states adhere to Environmental Protection Agency (EPA) guidelines that allow a dose of 2 rem in the first year and 500 mrem per year thereafter. The EPA recommendation has traditionally been implemented in MACCS2 as 4 rem during the first 5 years (2 rem + 4 * 0.5 rem) of exposure. However, Pennsylvania has a more strict habitability criterion of 500 mrem/yr beginning in the first year, and this value was used in the Peach Bottom analysis. The hotspot and normal relocation values used in NUREG-1150 were 0.5 Sv (50 rem) and 0.25 Sv (25 rem) respectively. The long term habitability criteria used in NUREG-1150 was 0.04 Sv (4 rem) over a 5 year period. The values used in SOARCA were revised to better align with site specific response expectations and EPA protective action guidelines. For example, the habitability criteria used for the Peach Bottom site in the SOARCA project was 5 mSv (500 mrem).

6.2.2 Shielding Factors

Shielding factors vary by geographical region across the United States, and those used in the Peach Bottom analysis are shown in Table 11. The factors represent the fraction of dose that a person would be exposed to when performing normal activities, evacuating, or staying in a shelter in comparison to a person outside with full exposure and are applied to all cohorts except the Special Facilities. Special Facilities are typically larger and more robust structures than housing stock and therefore have better shielding factors as identified in the table.

Table 11 Peach Bottom Shielding Factors.

Cohort	Ground Shine			Cloud Shine			Inhalation/Skin		
	Normal	Evac.	Shelter	Normal	Evac.	Shelter	Normal	Evac.	Shelter
Non-special facilities	0.18	0.50	0.10	0.60	1.00	0.50	0.46	0.98	0.33
Special Facilities	0.05	0.50	0.05	0.31	1.00	0.31	0.33	0.98	0.33

The shielding factors provided in Table 11 were obtained from a variety of sources. Where appropriate, site specific values for sheltering were obtained from NUREG-1150 [9]. An updated inhalation/skin evacuation shielding factor was obtained from NUREG/CR-6953, Vol. 1 [20]. The normal activity shielding factors have been adjusted to account for the understanding that people do not spend a great deal of time outdoors. The normal activity values are all weighted averages of indoor and outdoor values based on being indoors 81 percent of the time and outdoors 19 percent of the time [30]. The shielding factor value for indoor activities was assumed to be the same as the shielding factor value for sheltering shown in Table 11.

6.2.3 Potassium Iodide

Pennsylvania implements a potassium iodide (KI) program, and the State distributes KI tablets through several different means. The Department of Health district offices are responsible for coordinating with county emergency management agency officials to make KI available to residents living and working within the EPZ. The distribution of KI occurs on an annual basis for the Peach Bottom EPZ and is preceded by public announcements.

The purpose of the KI is to saturate the thyroid gland with stable iodine so that further uptake of radioactive iodine by the thyroid is diminished. If taken at the right time and in the appropriate dosage, KI can nearly eliminate doses to the thyroid gland from inhaled radioiodine. Factors that contribute to effectiveness of KI include the availability of KI, i.e., whether residents can find their KI, the timing of ingestion, and the degree of pre-existing stable iodine saturation of the thyroid gland which already inhibits absorption of inhaled radioiodine by the thyroid. It is considered that some residents will not remember where they have placed their KI or may not have it available and will therefore not take KI. It is also assumed some residents will not take their KI when directed (i.e., they may take it early or late which reduces the efficacy). To account for this, KI was assumed to be taken by 50 percent of the public and the efficacy of the KI was set at 70 percent.

Dose coefficients for the thyroid gland assume a level of pre-existing iodine in the thyroid as part of the underlying biokinetic model. Clearly, any source of stable iodine in the diet or from ingestion of KI that lead to saturation of the thyroid inhibits subsequent uptake of inhaled radioiodine by the thyroid. Deviations from standard assumptions of dietary intake of stable iodine are not treated in the SOARCA analyses. Instead, these analyses are based on the dose coefficients for radioiodine published in FGR-13; reductions in thyroid doses due to ingestion of KI are relative to the doses implied by these dose coefficients.

6.2.4 Adverse Weather

Adverse weather is typically defined as rain, ice, or snow that affects the response of the public during an emergency. The affect of adverse weather on the mobilization of the public was not directly considered in establishing emergency planning parameters for this project because such a consideration more approximates a worst-case scenario. However, adverse weather was addressed in the movement of cohorts within the analysis. The ESPMUL parameter in WinMACCS is used to reduce travel speed when precipitation is occurring as indicated from the meteorological weather file. The ESPMUL factor was set at 0.7 which effectively slows down the evacuating public to 70 percent of the established travel speed when precipitation exists.

6.2.5 Modeling Using Evacuation Time Estimates

The purpose of using the ETE as a parameter in consequence modeling is to better approximate the real time actions expected of the public. Although consequence modeling has evolved to allow use of many cohorts and can address many individual aspects of each cohort, the approach to modeling evacuations is not direct. As stated earlier, evacuations include mobilizing and evacuating the public over a period of time, which is best modeled as a distribution of data. To use WinMACCS, this distribution of data must be converted into discrete events. For instance, upon the sounding of the sirens and issuance of the Emergency Alert System messaging, it is assumed all members of the public shelter and 1 hour later all members of the public enter the roadway network at the same time and begin to evacuate. In research of existing evacuations for technological hazards, it is shown that members of the public would actually enter the roadway network over a period of about an hour. It is not realistic that all vehicles would load simultaneously; however, this treatment within the model is necessary due to the current modeling abilities of WinMACCS.

Following the above constraint, it is necessary to establish reasonable speeds for each cohort. The speeds are derived from the ETE, and the elements that factor into the speeds include:

- Time to receive notification and prepare to evacuate (mobilization time);
- Time to evacuate; and
- Distance of travel.

The time to receive notification requires assurance that sirens sound when needed. In review of the Reactor Oversight Program data regarding sirens for Peach Bottom, the average siren performance indicator is 99.8 percent, indicating that sirens do perform when tested. It is recognized that loss of power accidents will result in the loss of power to some offsite areas of the EPZ. However, there is no reason to expect that the power will be out in the entire 10 mile EPZ. For this analysis, it is assumed that the offsite sirens would be sounded within much of the EPZ. For those areas where the power outage affects sirens, route alerting would be conducted and the time allocated for this in the analysis is sufficient.

A simple ratio of distance to time would show that evacuation of the 0 to 10 public from the 10 mile EPZ at Peach Bottom which has an ETE of 4 hours 15 minutes, would provide a speed of 2.4 mph. However, as indicated above, notification and preparation to evacuate are included in the ETE.

For the general public, a one hour delay to shelter is assigned to reflect the mobilization time where residents receive the warning and prepare to evacuate. If the one hour mobilization time is subtracted from the ETE (4:15 – 1 hour) there remains 3 hours and 15 minutes to travel a maximum of 10 miles. As observed in actual evacuations due to technological or other hazards, people perform these mobilization activities at varying times with some residents ready to evacuate quickly while others can take up to an hour or longer. While this cohort is sheltered, a greater shielding factor is applied, and while en route during the evacuation, a lower shielding factor is applied.

During the evacuation, roadway congestion occurs rather quickly and traffic exiting the EPZ begins to slow. In review of over 20 ETE studies, this congestion typically occurs in 1 to 2 hours depending upon the population density and roadway capacity of the EPZ and considering that the vehicles are loaded onto the roadway network as a distribution. In the SOARCA analysis, the 0-10 public is sheltered and preparing to evacuate for one hour. The public is then loaded onto the roadway and congestion is assumed to occur within 15 minutes. This total time of 1 hour 15 minutes for congestion to occur was established to be consistent with ETE studies.

The calculation of the speed of evacuees includes the first 15 minutes to the point when congestion occurs. For this first 15 minutes, evacuees are assumed to travel at 5 mph. This speed considers stop signs, traffic signals, and the build up of congestion, and the speed is comparable to ETE modeling results observed in the review of over 20 ETE studies. In the first 15 minutes at 5 mph, a distance of 1.25 miles has been traveled. At that time congestion is heavy and speeds slow for the next 8.75 miles.

The ETE is 4 hours 15 minutes for this cohort. Having sheltered and prepared to evacuate for 1 hour and then traveled the first 15 minutes at 5 mph, the remaining time is 3 hours (4:15 - 1 hour shelter - 15 minutes at 5 mph). To determine the speed of travel for the remaining 8.75 miles, the distance is divided by the time (8.75 miles / 3 hours) which provides a speed of 2.9 mph. The calculated speed used in the analysis for this cohort was rounded to 3 mph for this cohort. The values were rounded to avoid implying that speeds are precise to two significant digits.

6.2.6 Cohort Modeling

The WinMACCS parameters for the cohorts are stored in multi-dimensional arrays, and the dimensions of the arrays are defined by geographical area for the analysis. WinMACCS requires the dimensions be established with the first cohort. All subsequent cohorts must be defined within these array dimensions, meaning they can extend from the origin to any distance equal to or less than the maximum distance established with the first cohort.

Cohort 1 was defined as the 0 to 10 mile public and has the same response characteristics as Cohort 2. The cohort that extends the greatest distance and defines the limits of the array is the Shadow Evacuation, which is Cohort 2. Thus, in the WinMACCS model, Cohorts 1 and 2 had to be redefined to meet the above requirement. The WinMACCS model input parameters for Cohort 1 were extended from the plant out to the maximum array distance of 20 miles, and Cohort 2 extends from the plant out to 10 miles. In the WinMACCS input file, Cohort 1 is input as 20 percent of the population from 0 to 20 miles. This captures the 20 percent of the population between 10 and 20 miles involved in the shadow evacuation beyond the EPZ. Cohort

2 is input as 35.5 percent of the population from 0 to 10 miles. The combination of Cohorts 1 and 2 from 0 to 10 miles in the WinMACCS model represent the Public (0 – 10) Cohort defined above. For the remaining cohorts, application of parameters in the WinMACCS model is direct, and the population fractions directly correspond to the cohort descriptions.

6.3 Accident Scenarios

An emergency response timeline was developed for each accident scenario using information from the MELCOR analyses, expected timing of Emergency Classification declarations, and information from the ETE. The timeline identifies points at which cohorts would receive instruction from OROs to implement protective actions. In practice, initial evacuation orders are based on the severity of the accident and in Pennsylvania would likely include an evacuation of the entire EPZ. The emergency planning parameters use a normal workday event, whereas the MELCOR analyses assumes minimum staffing consistent with an off-hours event. This adds some conservatism to the analysis because an off-hours, nighttime evacuation would typically occur a little faster because most residents are at home and schools are not in session. Therefore families would mostly evacuate directly from home.

6.3.1 LTSBO Unmitigated

The timing of emergency classification declarations was based on Table PBAPS 3-1 Emergency Action Level (EAL) Matrix contained in site emergency plan implementing procedures. The emergency classification timing was reviewed with the licensee for accuracy. The SAE EAL MS1 specifies that an SAE is declared 15 minutes after the initiating event (loss of all AC power). An EAS message is broadcast in response to the SAE providing warning and notification to residents and transients within the EPZ that there is an incident and instructing them to monitor the situation for further information. Sirens sound about 45 minutes after the SAE is declared. A GE is declared, based on EAL MG1, 45 minutes into the event (coincidentally 15 minutes prior to the issue of the first EAS message) when it is assumed operators have determined offsite power will not be restored within 2 hours. An EAS message regarding the GE is then broadcast, and sirens sound again, 45 minutes after the GE and 30 minutes following the initial EAS message regarding the SAE (see Figure 600). The EAS message for the GE would include instructions for implementing protective actions.

Discussions were held with site representatives to help ensure SOARCA staff properly understand the EALs for each accident scenario and emergency response practices. In addition, exercise timelines that show the times for notification of an emergency declaration, siren activation and broadcast of EAS messaging for Peach Bottom were reviewed. The timing in the exercises shows approximately 50 minutes from notification to sirens sounding, and as indicated in Figure 600, an estimate of 45 minutes (for example from SAE to SAE siren) was used in the analysis which closely approximates the exercise values. The offsite emergency plans for Peach Bottom include sounding sirens for both declaration of SAE and GE. The emergency response timeline for the long term station blackout scenario is shown in Figure 60. The duration of specific protective actions for each cohort are summarized in Figure 61.

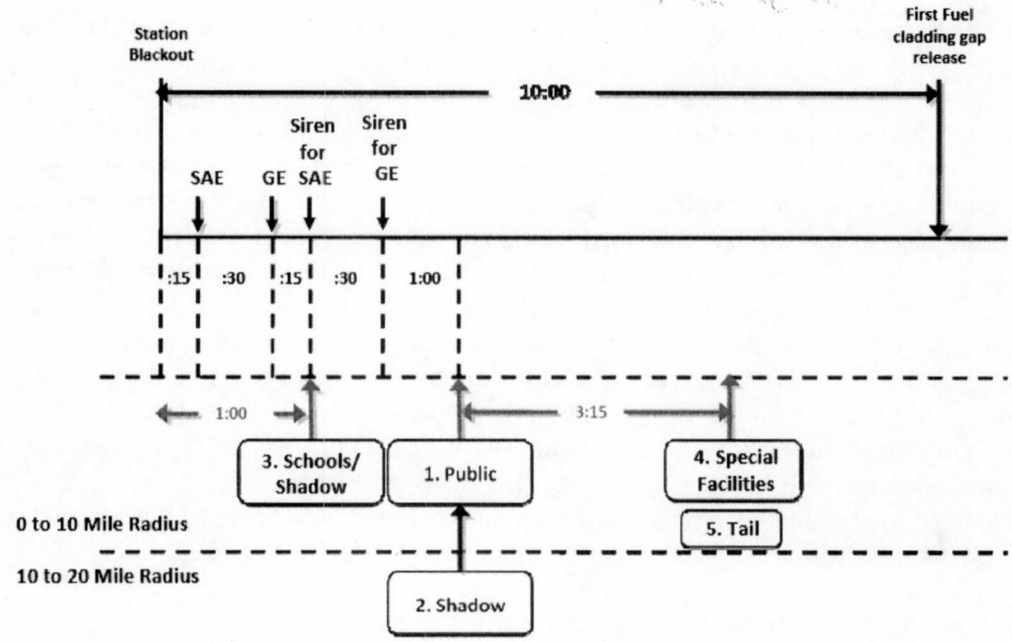


Figure 60 Unmitigated LTSBO Emergency Response Timeline

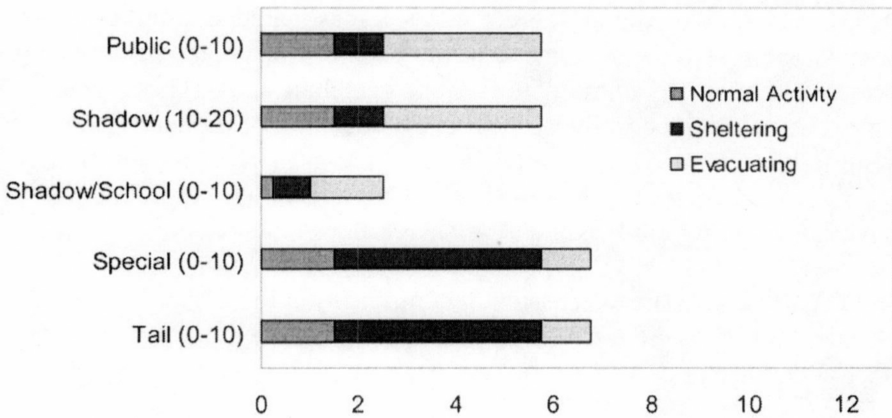


Figure 61 Duration of Protective Actions for Unmitigated LTSBO

Cohort 1: 0 to 10 Public. Following declaration of the SAE, sirens are sounded, at which time the public is assumed to shelter. Sirens are again sounded following the declaration of GE. The time for the public to receive the warning and prepare to mobilize is assumed to be one hour after the siren sounds for the GEwhich is consistent with empirical data from previous evacuations [23].

Cohort 2: 10 to 20 Shadow. This cohort is assumed to begin movement at the same time as the 0 to 10 Public once widespread media broadcasts are underway. Residents in the 10 to 20 area begin seeing large numbers of people evacuating and initiate a shadow evacuation. There is no warning or notification for the public residing in this area which is not under an evacuation order.

Cohort 3: 0 to 10 Schools and 0 to 10 Shadow. Schools are the first to take action. Upon receipt of the declaration of SAE by the site, county emergency management agencies would notify the schools in accordance with the offsite emergency response plan. It is assumed schools begin sheltering when notified, and this notification is assumed to occur about 15 minutes after the emergency declaration. Buses would be mobilized, but in accordance with the emergency plan, evacuation would not begin until a GE is declared. The preliminary action to mobilize buses in response to the SAE allows for a prompt evacuation. It is assumed schools begin evacuating 15 minutes after GE, and it is only coincidence that this occurs about the same time as the sounding of the sirens in response to the SAE. At this time in the event, roads are uncongested and school buses are able to exit the EPZ quickly. It is assumed that sounding of sirens and broadcast of the EAS message for the SAE causes a shadow evacuation of residents within the EPZ (0 to 10 Shadow). Because the shadow population is grouped with the schools (see Section 6.1), the shadow population is also treated as if it shelters at 15 minutes.

Cohort 4: 0 to 10 Special Facilities. Special Facilities can take longer to evacuate than the general public because transportation resources, some of which are specialized, such as wheelchair vans and ambulances must be mobilized. Special facilities evacuate individually with each facility responsible for obtaining resources. These resources are required to have been established during emergency planning; therefore, it is a reasonable assumption that the resources will be available. However, some facilities require specialized resources of which there may be few available, such as ambulances and wheelchair vans. These types of vehicles sometimes must make return trips until everyone is evacuated. For modeling convenience, the conservative assumption was made that the residents of these facilities remain sheltered and evacuate in a single wave beginning when the Tail cohort begins to evacuate recognizing that some facilities would actually mobilize and evacuate earlier in the event.

Cohort 5: 0 to 10 Tail. Using the evacuation data provided in the Peach Bottom ETE [28], 90 percent of the evacuation of the EPZ is complete at approximately 4 hours and 15 minutes, and this corresponds to the departure time for the 0 to 10 Tail.

Cohort 6: Non-Evacuating Public. This cohort group represents a portion of the public who may refuse to evacuate and is assumed to be 0.5 percent of the population. Any member of the public who does not evacuate is still subject to the Hotspot and Normal Relocation criterion discussed earlier.

The evacuation timing and speeds for each cohort are presented in Table 12. Selected input parameters for WinMACCS are provided in Table 12 to support detailed use of this study. More detailed information regarding modeling parameters is available in the MACCS2 User's Guide [24]. A brief description of the parameters is provided below.

- Delay to Shelter (DLTSHL) represents a delay from the time of the start of the accident until cohorts enter the shelter. Delay to Shelter is generally referenced to alarm time, but the value (OALARM) is set to zero in these analyses.

- Delay to Evacuation (DLTEVA) represents the length of the sheltering period from the time a cohort enters the shelter until the point at which they begin to evacuate.
- The speed (ESPEED) is assigned for each of the three phases used in WinMACCS including Early, Middle, and Late. Average evacuation speeds were derived from the Peach Bottom ETE report. Speed adjustment factors were then utilized in the WinMACCS application to represent free flow in rural areas and congested flow in urban areas.
- Duration of Beginning phase (DURBEG) is the duration assigned to the beginning phase of the evacuation and may be assigned uniquely for each cohort.
- Duration of Middle phase (DURMID) is the duration assigned to the middle phase of the evacuation and may also be assigned uniquely for each cohort.

For the 0 to 10 Public and the 0 to 10 Tail, the sum of the DLTEVA, DURBEG and DURMID is equal to the ETE.

Table 12 Unmitigated LTSBO Cohort Timing

Cohort	Delay to Shelter DLTSHL (hr)	Delay to Evacuation DLTEVA (hr)	DURBEG (hr)	DURMID (hr)	ESPEED[a] (early) mph	ESPEED[a] (mid) mph
0 to 10 Public	1.5	1	0.25	3	5	3
10 to 20 Shadow	1.5	1	0.25	3	5	3
0 to 10 Schools/Shadow	0.25	0.75	1	0.5	20	20
0 to 10 Special Facilities	1.5	4.25	0.5	0.5	3	20
0 to 10 Tail	1.5	4.25	0.5	0.5	3	20
Non-Evac	0	0	0	0	0	0

[a] – 20 mph was used for the late phase evacuation speed for all cohorts.

6.3.2 STSBO with RCIC Blackstart

The timing of emergency classification declaration for the STSBO with RCIC blackstart was based on Table PBAPS 3-1 Emergency Action Level (EAL) Matrix contained in site emergency plan implementing procedures. The emergency classification timing was reviewed with the licensee for accuracy and this scenario is an immediate GE. With loss of offsite power and loss of DC power, operators cannot determine whether water level is above TAF, and a GE is declared based on EAL MG1. The emergency response timeline for the STSBO scenario is shown in Figure 62 and protective action durations for each cohort are shown in Figure 63. Core damage, as evidenced by the first fuel cladding gap release, is calculated at 5 hours into the event, with a significant radioactive release from containment beginning 13 hours into the event as indicated by the lower head failure notation in Figure 62.

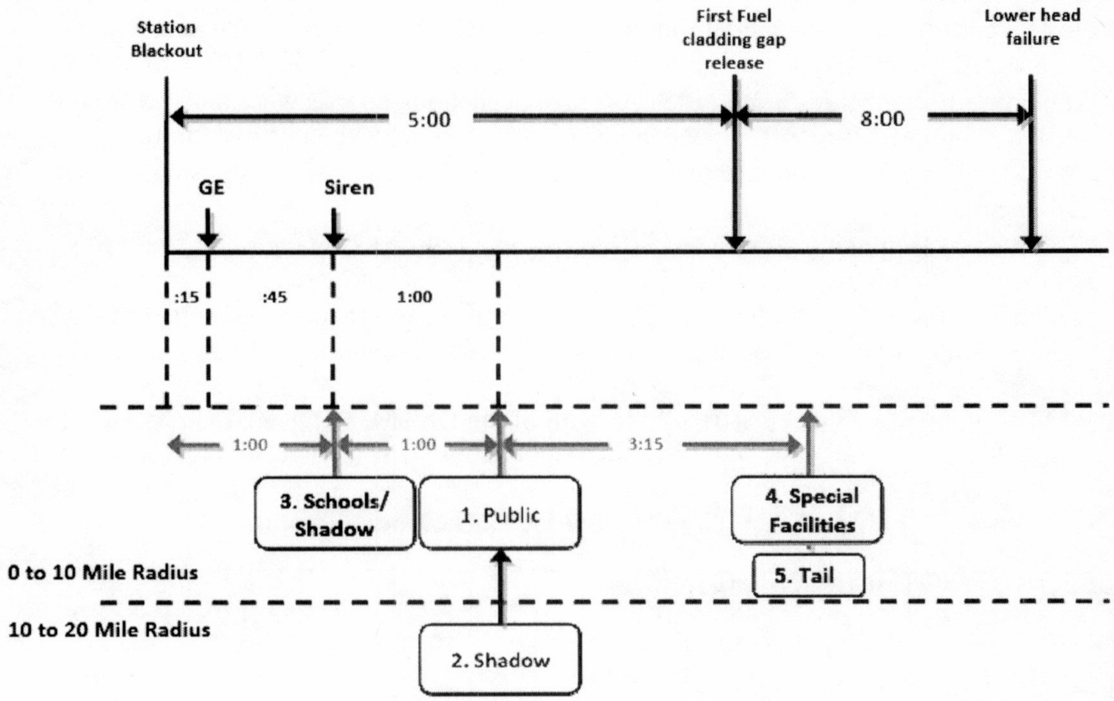


Figure 62 STSBO with RCIC Blackstart Emergency Response Timeline

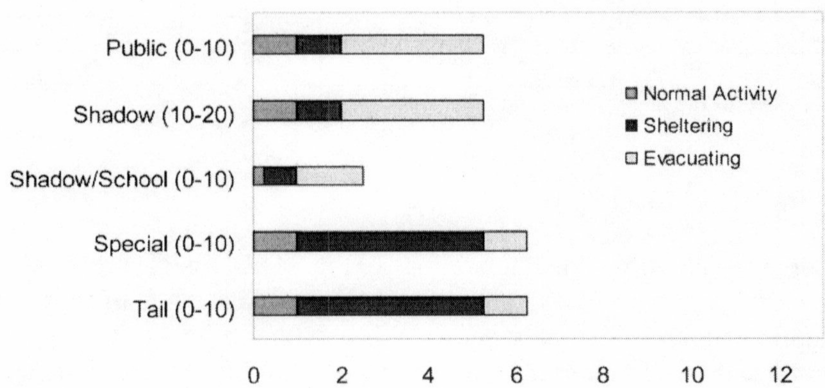


Figure 63 Protective Actions for STSBO with RCIC Blackstart

Cohort 1: 0 to 10 Public. It is assumed to take 45 minutes for OROs to sound sirens following declaration of a GE, at which point the public is assumed to shelter. The time for the public to receive the warning and prepare to mobilize is assumed to be 1 hour after the siren sounds for the GE.

Cohort 2: 10 to 20 Shadow. This cohort is assumed to begin movement at the same time as the 0 to 10 Public once widespread media broadcasts are underway.

Cohort 3: 0 to 10 Schools and 0 to 10 Shadow. This cohort is the first to take action. Upon receipt of the declaration of GE, county emergency management agencies would notify the schools in accordance with the emergency response plan. It is assumed that schools begin sheltering when notified, buses are mobilized, and evacuation would begin about 45 minutes after the GE is declared. It is coincidence that evacuation of the schools occurs at the same time sirens are assumed to sound. The sounding of the sirens for GE is not directly linked to evacuation of the schools.

It is noted that the schools begin to evacuate in one hour which is the same as the LTSBO. This is a coincidence in timing. For the LTSBO, school buses are mobilized at the SAE and ready for deployment. Once the GE is declared, the evacuation begins within about 15 minutes because the resources have been prepared. For the STSBO, buses begin to be mobilized when the GE is declared and the evacuation begins about 45 minutes later.

Cohort 4: 0 to 10 Special Facilities. Special Facilities are assumed to depart at the same time as the evacuation Tail.

Cohort 5: 0 to 10 Tail. The Tail begins to evacuate approximately 4 hours and 15 minutes after notification to evacuate.

Cohort 6: Non-Evacuating Public. This cohort group represents a portion of the 0 to 10 public that may refuse to evacuate and is assumed to be 0.5 percent of the population.

The delay to shelter identified in Table 13 represents a delay before people enter the shelter, and the delay to evacuation represents the length of the sheltering period prior to initiating evacuation. These delays correspond to the different shielding factors that would be applied to each cohort during these timeframes. The speeds in this table represent average movements for the cohorts as derived from the ETEs. These values are adjusted within each grid element when developing the WinMACCS model.

Table 13 STSBO with RCIC Blackstart Cohort Timing.

Cohort	Delay to Shelter DLTSHL (hr)	Delay to Evacuation DLTEVA (hr)	DURBEG (hr)	DURMID (hr)	ESPEED[a] (early) mph	ESPEED[a] (mid) mph
0 to 10 Public	1.00	1.00	0.25	3.00	5	3
10 to 20 Shadow	1.00	1.00	0.25	3.00	5	3
0 to 10 Schools/Shadow	0.25	0.75	1.00	0.50	20	20
0 to 10 Special Facilities	1.00	4.25	0.50	0.50	3	20
0 to 10 Tail	1.00	4.25	0.50	0.50	3	20
Non-Evac	0	0	0	0	0	0

[a] – 20 mph was used for the late phase evacuation speed for all cohorts.

6.3.3 STSBO without RCIC Blackstart

The timing of emergency classification declaration for the STSBO without RCIC blackstart was based on Table PBAPS 3-1 Emergency Action Level (EAL) Matrix contained in site emergency plan implementing procedures. The emergency classification timing was reviewed with the licensee for accuracy and this scenario is an immediate GE. With loss of offsite power and loss of DC power, operators cannot determine whether water level is above TAF, and a GE is declared based on EAL MG1. The emergency response timeline for the STSBO without RCIC blackstart scenario is shown in Figure 64 and protective action durations for each cohort are shown in Figure 65. Core damage, as evidenced by the first fuel cladding gap release, is calculated at 1 hour into the event, with a significant radioactive release from containment beginning 8 hours into the event as indicated by the lower head failure notation in Figure 64.

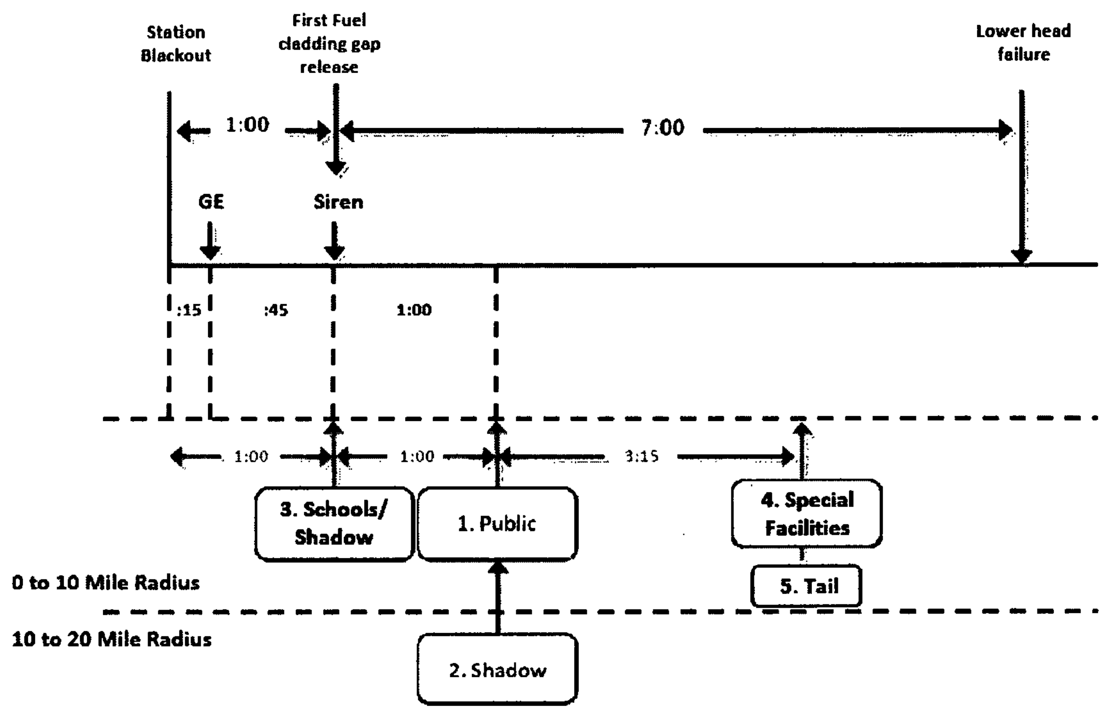


Figure 64 STSBO without RCIC Blackstart Emergency Response Timeline

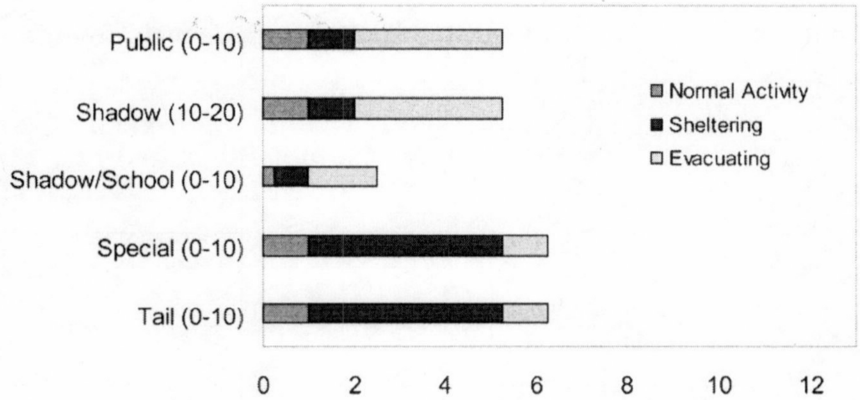


Figure 65 Duration of Protective Actions for STSBO without RCIC Blackstart

The implementation of protective actions for the STSBO without RCIC blackstart is the same as implementation for the STSBO with RCIC blackstart.

Cohort 1: 0 to 10 Public. It is assumed to take 45 minutes for OROs to sound sirens following declaration of a GE, at which point the public is assumed to shelter. The time for the public to receive the warning and prepare to mobilize is assumed to be one hour after the siren sounds for the GE.

Cohort 2: 10 to 20 Shadow. This cohort is assumed to begin movement at the same time as the 0 to 10 Public once widespread media broadcasts are underway.

Cohort 3: 0 to 10 Schools and 0 to 10 Shadow. This cohort is the first to take action. Upon receipt of the declaration of GE by the site, county emergency management agencies would notify the schools in accordance with the emergency response plan. It is assumed schools begin sheltering when notified, buses would be mobilized, and evacuation would begin about 45 minutes after the GE is declared. It is coincidence that this occurs at the same time sirens are assumed to sound.

Cohort 4: 0 to 10 Special Facilities. Special Facilities are assumed to depart at the same time as the evacuation Tail.

Cohort 5: 0 to 10 Tail. The Tail begins to evacuate approximately 4 hours and 15 minutes after notification to evacuate.

Cohort 6: Non-Evacuating Public. This cohort group represents a portion of the 0 to 10 public that may refuse to evacuate and is assumed to be 0.5 percent of the population.

The delay to shelter, identified in Table 14 represents a delay before people enter the shelter, and delay to evacuation represents the length of the sheltering period prior to initiating evacuation. These delays correspond to the different shielding factors that would be applied to each cohort during these timeframes. The speeds in this table represent average movements for the cohorts. These values are adjusted within each grid element when developing the WinMACCS model.

Table 14 STSBO without RCIC Blackstart Cohort Timing.

Cohort	Delay to Shelter DLTSHL (hr)	Delay to Evacuation DLTEVA (hr)	DURBEG (hr)	DURMID (hr)	ESPEED[a] (early) mph	ESPEED[a] (mid) mph
0 to 10 Public	1.00	1.00	0.25	3.00	5	3
10 to 20 Shadow	1.00	1.00	0.25	3.00	5	3
0 to 10 Schools/Shadow	0.25	0.75	1.00	0.50	20	20
0 to 10 Special Facilities	1.00	4.25	0.50	0.50	3	20
0 to 10 Tail	1.00	4.25	0.50	0.50	3	20
Non-Evac	0	0	0	0	0	0

[a] – 20 mph was used for the late phase evacuation speed for all cohorts.

6.4 Sensitivity Studies

Analysis of emergency preparedness and reaponse parameters such as demographics, infrastructure, timing, etc., provide many areas for further evaluation through sensitivity studies. The project team selected three additional calculations to assess variations in the implementation of protective actions. Each of the sensitivity studies was conducted using the STSBO without RCIC blackstart accident scenario, which was selected because it represents an earlier release than the other scenarios.

- Sensitivity 1 – Evacuation of a 16 mile area and a shadow evacuation from within the 16 to 20 mile area.
- Sensitivity 2 – Evacuation of the 0 to 20 mile area.
- Sensitivity 3 – Delay in implementation of protective actions for the public within the EPZ.

Sensitivity 1 and 2 assessed the effects of expanding the initial protective actions to distances of 16 and 20 miles respectively. The objective of this sensitivity analysis was to determine whether consequences might be reduced if the initial evacuation area was larger. Twenty miles was selected because it is twice the distance of the EPZ. A middle distance was also desired and 16 miles was selected because the nodalization had been chosen to have a ring at this distance, but not one at 15 miles.

Sensitivity 3 assessed a delay in the implementation of protective actions for the public. Although there is high confidence that the licenses and OROs will respond promptly, following their procedures, the SOARCA peer review committee suggested a delay be considered. Such a delay might be caused by lack of communication, power outage, slower than expected decision process (by licensee or OROs), or other factors. The 30-minute period was selected based on review of response data from exercises at Peach Bottom, which show that the response times and actions typically varied by only a few minutes among different exercises.

The modeling of the area beyond the EPZ includes a full-scale evacuation for the sensitivity analysis, although this does not reflect likely protective action decisions. To support the assessment of implementing protective actions outside of the EPZ, an evacuation model was developed using data obtained for the 10 to 20 mile area around the NPP. Evacuation speeds for the cohorts in the 10 to 20 mile area were developed using OREMS Version 2.6. OREMS is a Windows-based application used to simulate traffic flow and was designed specifically for emergency evacuation modeling [22]. The main features of OREMS utilized in the analyses include:

- Determining the length of time associated with complete or partial evacuation of the population at risk within an emergency zone, or for specific sections of highway network or sub-zones; and
- Determining potential congestion areas in terms of traffic operations within the emergency zone.

The OREMS model considers special conditions that may be imposed during an emergency evacuation. For example, intersections that normally have pre-timed controllers are assumed to be manned by emergency personnel to facilitate traffic flow. This function is consistent with the emergency response actions that would be implemented during an evacuation. Detail for road networks was obtained from available mapping and was input into OREMS using the standard intersection functions available in the model. Judgment and experience were applied in determining the number of nodes established for the model. OREMS can manage hundreds of nodes, but there is a point at which the addition of nodes and links provides little change in the total times. For an urban area, a nodal network would be heavily populated and for a rural area, the network would be lightly populated. The nodal network established for this analysis would be considered a moderately populated network for this code because there is a mixture of rural and urban areas.

For the Peach Bottom 10 to 20 mile ETE, 232,053 vehicles were loaded onto 118 nodes of a 442 node network. The network loading was distributed over a five hour period to account for the trip generation time. The following evacuation times were derived from the OREMS calculation as plotted in Figure 66:

- 100 percent evacuation: 19 hours;
- 90 percent evacuation: 12 hours and 15 minutes

These times were used to derive the evacuation speeds input into the WinMACCS model. The evacuation modeling conducted for the Peach Bottom plant was developed consistent with the characteristics observed in prior evacuations conducted for non-nuclear incidents. As described earlier, the analysis includes the common phenomenon of evacuations in which travelers who depart the threat zone the earliest experience shorter delays because the routes have yet to become fully utilized during the emergency. Evacuees who depart during the middle part of the evacuation, when the greatest numbers of people are seeking to depart, generally experience the highest congestion and longer delay because the demand on the roadway network is at its greatest, exceeding the available capacity in many areas. Evacuees who depart the hazard zone later enter the network as the demand nears, or goes below, the roadway capacity and they are also able to avoid the delays associated with the peak evacuation demand period. The ETE modeling indicates most congestion occurs in the more populous areas in the north near Lancaster, Pennsylvania, and in the south near Forest Hill, Bel Air, and Fallston, Maryland.

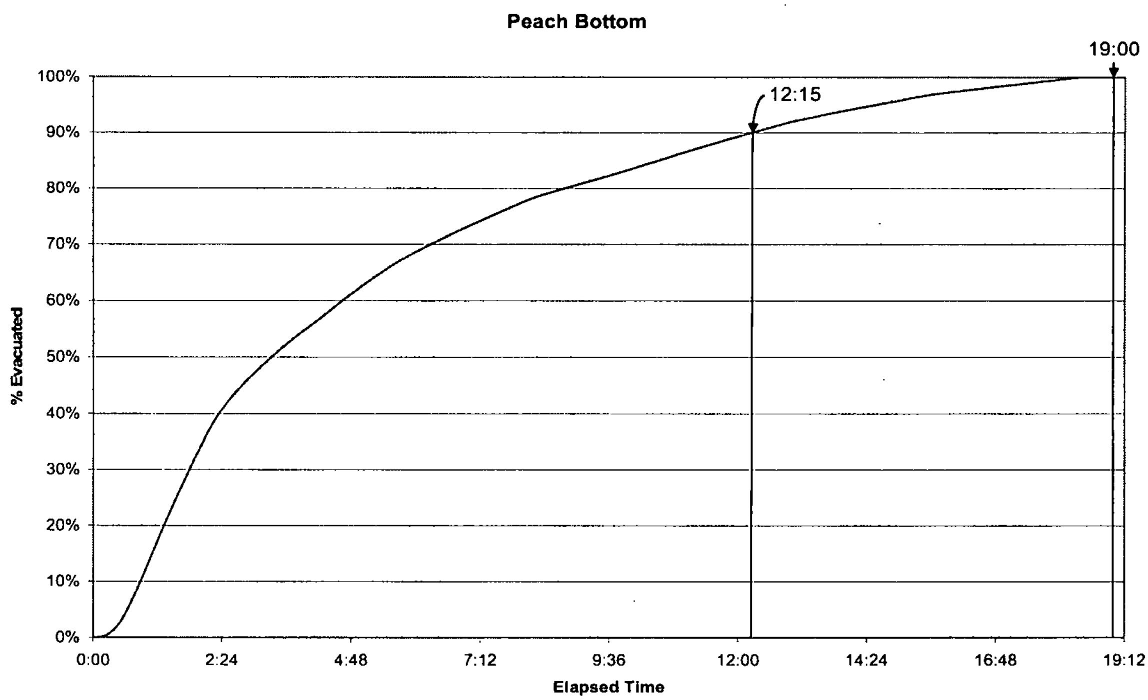


Figure 66 Evacuation Timeline from Peach Bottom for the 10 to 20 Mile Region

The initial accident scenarios were evaluated for protective actions within the EPZ. Expanding the protective actions to distances beyond the EPZ is not readily accommodated using the modeling approach selected for these analyses. Therefore, although OROs may request that the 10 to 20 population shelter, this population group is treated as performing normal activities throughout the emergency. The normal activity shielding factors are weighted averages of indoor and outdoor values based on being indoors 81 percent of the time and outdoors 19 percent of the time [30]. The hotspot and normal relocation model within MACCS2 will move affected individuals out of the area if the dose criteria apply.

6.4.1 Sensitivity 1 for the STSBO without RCIC Blackstart Evacuation to 16 Miles

For Sensitivity 1, evacuation of a 16 mile area around the NPP is assessed. In addition, a Shadow evacuation occurs from within the 16 to 20 mile area, and the remaining members of the public in the 16 to 20 mile area were modeled as performing normal activities as described above. Figure 67 identifies the cohort timing for Sensitivity 1 and the durations of protective actions for each cohort are shown in Figure 68.

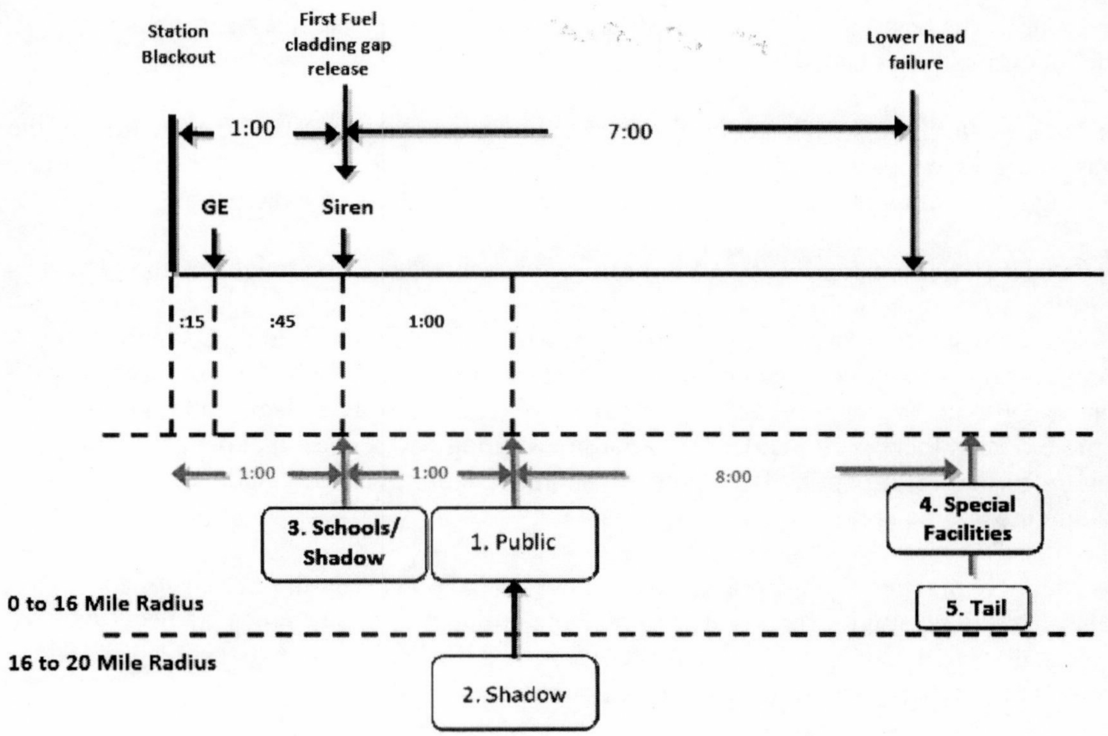


Figure 67 Sensitivity 1 STSBO without RCIC Blackstart - Evacuation to 16 Miles

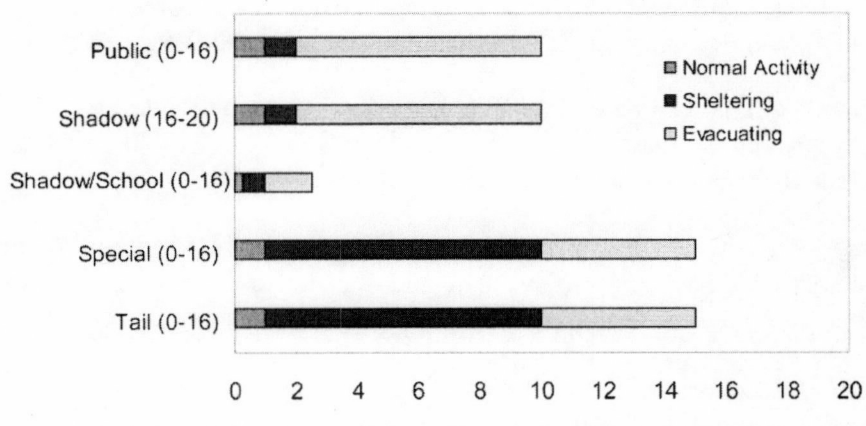


Figure 68 Duration of Protective Actions for Sensitivity 1 STSBO without RCIC Blackstart - Evacuation to 16 Miles

Cohort 1: 0 to 16 Public. Following declaration of a GE, sirens are sounded and an EAS message is broadcast to the affected areas within the EPZ. The public is assumed to shelter when the sirens sound, and the time to receive the warning and prepare to mobilize is assumed to be 1 hour. An assumption in this sensitivity analysis is that the 16 to 20 public would be notified at the same time as the EPZ via EAS messaging and route alerting. The ETE for the public was estimated as a linear projection between the Peach Bottom ETE study and the 10 to 20 mile ETE developed for the Sensitivity 2 analysis. Therefore, although the evacuation of the public starts at the same time as the base case, it takes longer to evacuate the area as indicated in Table 15 which shows longer travel times and slower speeds.

Cohort 2: **16 to 20 Shadow.** This cohort is assumed to begin movement at the same time as the 0 to 16 Public once widespread media broadcasts are underway. Residents in the 16 to 20 area begin seeing large numbers of people evacuating and initiate a Shadow evacuation.

Cohort 3: 0 to 16 Schools and 0 to 16 Shadow. This cohort is the first to take action. Upon receipt of the declaration of GE by the site, county emergency management agencies would notify the schools in accordance with the emergency response plan. It is assumed schools begin sheltering in about 15 minutes, and begin evacuating 45 minutes after GE. The sounding of sirens in response to the GE provides warning and notification to all residents and transients within the EPZ that there is an incident, and EAS messaging will request that people monitor the situation for further information. It is assumed that these actions cause a Shadow evacuation from within the 0 to 16 area.

Schools routinely practice fire drills and have callout lists to quickly notify parents of an emergency. In the sensitivity study, it is assumed the initial projections indicate a need for protective actions to a distance of 16 miles. It is assumed that within 1 hour, schools beyond the EPZ would notify parents and mobilize evacuation efforts.

Cohort 4: 0 to 16 Special Facilities. All Special Facilities are required to have evacuation plans, and in this scenario it is assumed that the facilities within the 0 to 16 mile area would evacuate. The Special Facilities cohort is modeled to depart at the same time as the evacuation tail although in reality, facilities would be evacuating as resources become available. As shown in Table 15, the delay to evacuation is longer than the base case and the speed is slower

Cohort 5: 0 to 16 Tail. A estimate of the departure for the evacuation tail is established as a linear projection between the Peach Bottom ETE and the OREMS 10 to 20 mile ETE developed for evacuation to a distance of 20 miles from the plant.

Cohort 6: Non-Evacuating Public. This cohort group represents a portion of the public within the 0 to 16 mile area who may refuse to evacuate and is assumed to be 0.5 percent of the population.

Table 15 identifies the cohort timing for Sensitivity 1.

Table 15 STSBO without RCIC Blackstart, Sensitivity 1

Cohort	Delay to Shelter DLTSHL (hr)	Delay to Evacuation DLTEVA (hr)	DURBEG (hr)	DURMID (hr)	ESPEED[a] (early) mph	ESPEED[a] (mid) mph
0 to 16 Public	1.00	1.00	0.25	7.75	5	2
16 to 20 Shadow	1.00	1.00	0.25	7.75	5	2
0 to 16 Schools/Shadow	0.25	0.75	1.00	0.50	20	20
0 to 16	1.00	9.00	4.00	1.00	2	20

Special Facilities						
0 to 16 Tail	1.00	9.00	4.00	1.00	2	20
Non-Evac	0	0	0	0	0	0

[a] – 20 mph was used for the late phase evacuation speed for all cohorts.

6.4.2 Sensitivity 2 for the STSBO without RCIC Blackstart Evacuation to 20 Miles

For Sensitivity 2, evacuation of a 20 mile area around the NPP is assessed. Because the initial evacuation is extended to 20 miles, no further shadow evacuation was considered. Table 16 identifies the cohort timing for Sensitivity 2. The cohort timing and protective action durations are shown in Figure 69 and Figure 70 respectively for this sensitivity case.

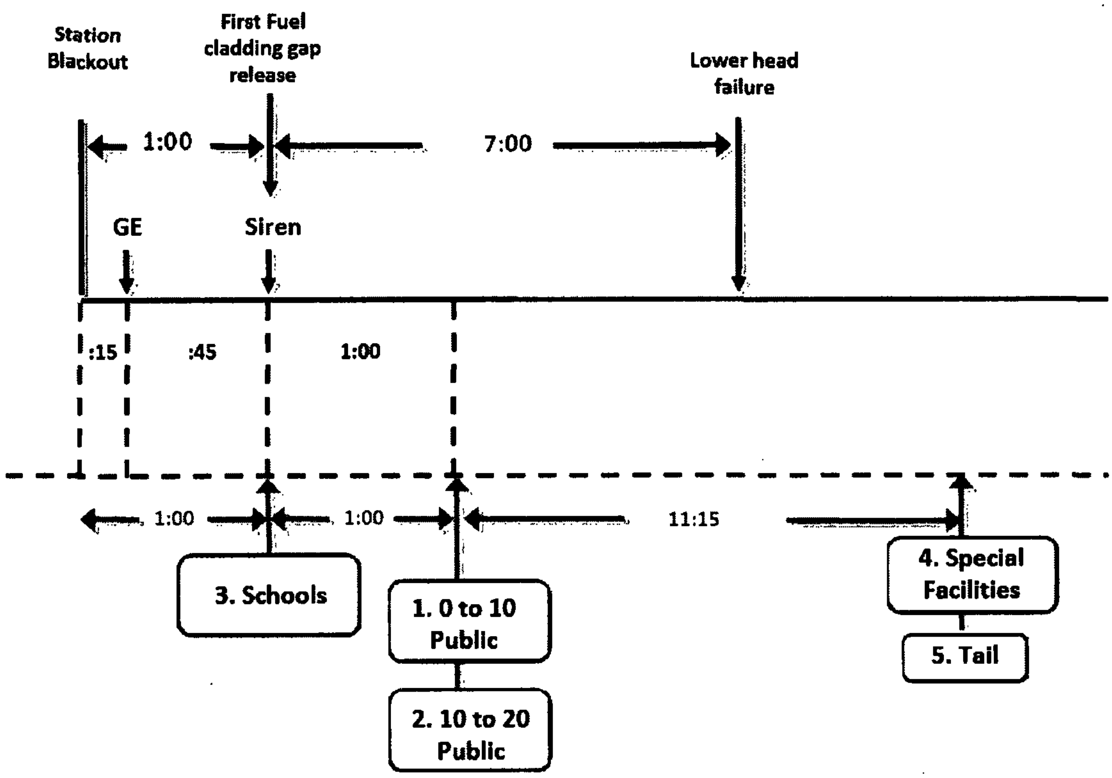


Figure 69 Sensitivity 2 STSBO without RCIC Blackstart - Evacuation to 20 Miles

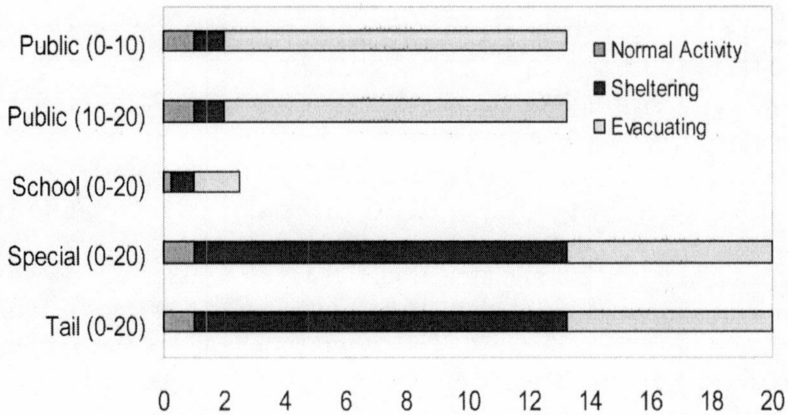


Figure 70 Duration of Protective Actions for Sensitivity 2 STSBO without RCIC Blackstart - Evacuation to 20 Miles

Cohort 1: 0 to 10 Public. Following declaration of a GE, sirens are sounded within the EPZ and an evacuation order would be issued for the EPZ. The time to receive the warning and prepare to mobilize is assumed to be 1 hour. Therefore, although the evacuation of the public starts at the same time as the base case, it takes longer to evacuate the area as indicated in Table 16 which shows longer travel times and slower speeds.

Cohort 2: 10 to 20 Public. Following declaration of a GE, sirens are sounded within the EPZ and an evacuation order would be issued for the EPZ. An assumption in this sensitivity analysis is that the 10 to 20 public would be notified at the same time as the EPZ via EAS messaging and route alerting. The time to receive the warning and prepare to mobilize is still assumed to be 1 hour after the initial notification. The ETE for the 10 to 20 public was calculated using OREMS.

Cohort 3: 0 to 20 Schools. Upon receipt of the declaration of GE by the site, county emergency management agencies would notify the schools within the EPZ in accordance with the emergency response plan. For this sensitivity study, is assumed schools beyond the EPZ would decide, based upon media information that it is prudent to evacuate or close schools immediately. In this sensitivity study, it is assumed the initial projections indicate a need for protective actions to a distance of 20 miles. It is assumed that within 1 hour, schools beyond the EPZ would notify parents and mobilize evacuation efforts.

Cohort 4: 0 to 20 Special Facilities. For this sensitivity study, it is assumed that Special Facilities beyond the EPZ would decide, based upon media information that it is prudent to evacuate. Therefore, the Special Facilities cohort is modeled to depart at the same time as the evacuation tail. As shown in Table 16, the delay to evacuation is longer than the base case and the speed is slower.

Cohort 5: 0 to 20 Tail. The ETE for the evacuation tail was estimated based on the OREMS analysis. This cohort shelters upon hearing the sirens and begins evacuating 12 hours and 15 minutes later. As shown in Table 16, the delay to evacuation is longer than the base case and the speed is slower.

Cohort 6: Non-Evacuating Public. This cohort group represents a portion of the public within the 0 to 20 mile area who may refuse to evacuate and is assumed to be 0.5 percent of the population.

Table 16 identifies the cohort timing for Sensitivity 2.

Table 16 STSBO without RCIC Blackstart, Sensitivity 2.

Cohort	Cohort#	Delay to Shelter DLTSHL (hr)	Delay to Evacuation DLTEVA (hr)	DURBEG (hr)	DURMID (hr)	ESPEED[a] (early) mph	ESPEED[a] (mid) mph
0 to 10 Public	1	1.00	1.00	0.25	11.00	5	1.8
10 to 20 Public	2	1.00	1.00	0.25	11.00	5	1.8
0 to 20 Schools	3	0.25	0.75	1.0	0.5	20	20
0 to 20 Special Facilities	4	1.00	12.25	5.75	1.00	1.8	20
0 to 20 Tail	5	1.00	12.25	5.75	1.00	1.8	20
Non-Evac	6	0	0	0	0	0	0

[a] – 20 mph was used for the late phase evacuation speed for all cohorts.

6.4.3 Sensitivity 3 for the STSBO without RCIC Blackstart with a Delay in Implementation of Protective Actions

The initiation event for the STSBO without RCIC blackstart and a GE is declared based on EAL MG1. Although there is a high level of confidence regarding the actions expected from control room operators and ORO response, the peer review committee suggested a delay of the implementation of protective actions be considered. Such a delay could be from delay in control room declaration of an incident, delay in the decision process of OROs, or delay in communication to the public regarding implementation of protective actions. To address the potential for delay, an additional protective action timeline has been developed for the STSBO without RCIC blackstart. This timeline reflects a delay in the implementation of protective actions by the public within the EPZ. Because protocols and procedures are in place, exercised and tested frequently, it is assumed that a delay of 30 minutes is adequate for this sensitivity study. The cohort timing and protective action durations are shown in Figure 71 and Figure 72 for this sensitivity case.

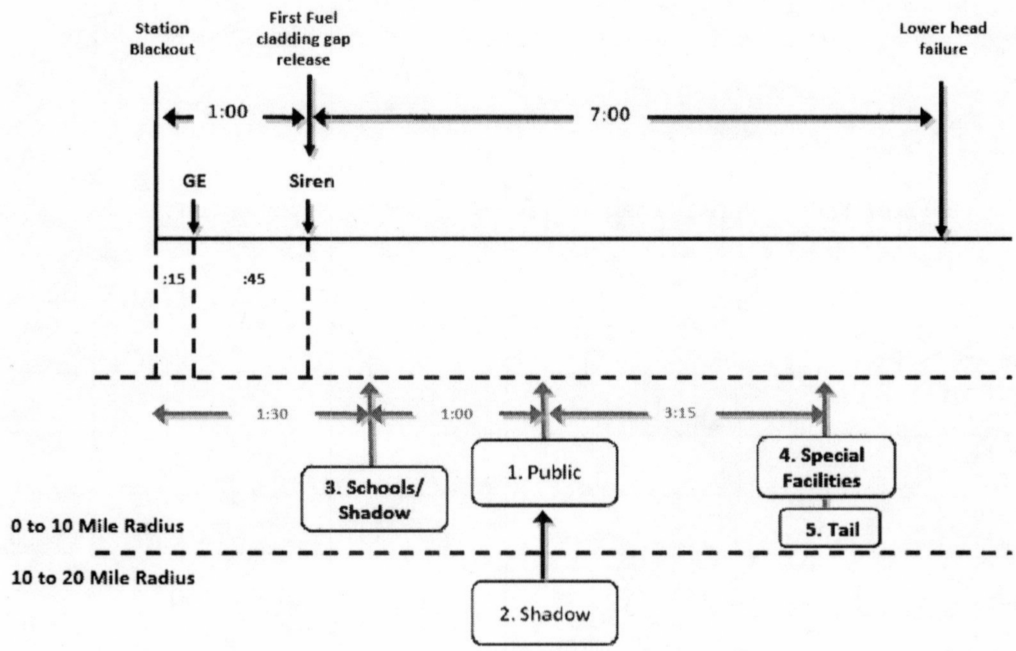


Figure 71 Sensitivity 3 STSBO without RCIC Blackstart - Delay in Implementation of Protective Actions

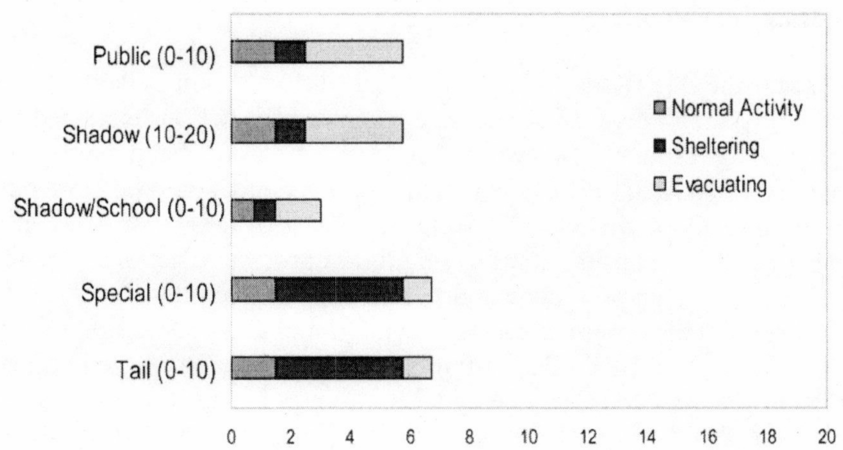


Figure 72 Protective Action Durations for Sensitivity 3 STSBO without RCIC Blackstart - Delay in Implementation of Protective Actions

The 30 minute delay was added to the 'delay to shelter' parameter for all cohorts. The remaining delay and speed parameters remained unchanged from the base case. By allocating the delay at this point, all cohort actions move to the right on the timeline by 30 minutes and the sum of DLTEVA, DURBEG, and DURMID still equates to the ETE for the public and the tail. Table 17 identifies the cohort timing for Sensitivity 3.

Table 17 Cohort Timing for Sensitivity 3

Cohort	Delay to Shelter DLTSHL (hr)	Delay to Evacuation DLTEVA (hr)	DURBEG (hr)	DURMID (hr)	ESPEED[a] (early) mph	ESPEED[a] (mid) mph
0 to 10 Public	1.50	1.00	0.25	3.00	5	3
10 to 20 Shadow	1.50	1.00	0.25	3.00	5	3
0 to 10 Schools/Shadow	0.75	0.75	1.00	0.50	20	20
0 to 10 Special Facilities	1.50	4.25	0.50	0.50	3	20
0 to 10 Tail	1.50	4.25	0.50	0.50	3	20
Non-Evac	0	0	0	0	0	0

[a] – 20 mph was used for the late phase evacuation speed for all cohorts.

6.5 Analysis of Earthquake Impact

A seismic analysis was developed to assess the potential effects on local infrastructure (e.g., roadways and bridges), communications, and emergency response in the event of a large scale earthquake. The accident scenario used in the earthquake analysis is the STSBO without RCIC blackstart, which was selected because this scenario represents an earlier release than the other scenarios. Integrating the effects of the earthquake into the analysis required assessing the damage potential of the earthquake, identification of parameters that would be affected, and determining the new values for affected parameters.

The potential for an earthquake is largely identified by the occurrence of previous earthquakes in the region. Understanding of where earthquake faults exist in the eastern United States is not robust, whereas, in the west geological fault lines can be identified on the surface. Faults in the east are usually buried below layers of soil and rock and are not identifiable making prediction of earthquake location and magnitude difficult. The earthquakes hypothesized in SOARCA are assumed to be close to the plant site, and it may be assumed that severe damage is generally localized. Housing stock would generally survive the earthquake, with some damage. The local electrical grid is assumed to be out of service from the failure of lines, switch yard equipment, or other impacts.

There is currently no back up power system for the sirens at Peach Bottom, and it is assumed that offsite response organizations would perform route alerting to notify the population of the need to take protective actions. This is a routine and effective method of informing the public to implement protective actions [19]. Under these postulated conditions, the potential for such an earthquake to affect emergency response and public evacuation is considered.

6.5.1 Soils Review

To approximate the extent of damage, an evaluation of the potential failure of infrastructure was conducted by NRC seismic experts to determine which, if any, roadways or bridges may fail under the postulated earthquake conditions. The assessment was performed using readily available information and professional judgment. Existing information on basic bedrock geology of the region was developed from reports and papers from the United States Geological Service (USGS), Pennsylvania Geological Survey, Maryland Geological Survey, and FSAR for the Peach Bottom plant. Generalized soils information was developed from Natural Resources Conservation Service (NRCS) soil survey information for York and Lancaster counties, Pennsylvania. It is assumed for this analysis that the generalized soil characteristics are applicable to the entire region.

The NRCS reports break the soils into several distinct, descriptive units. The units of interest to the present evaluation are the Chester-Gleneig, Mt. Airy-Manor, Grenville, and Codorus soil groups. These are generally well-drained soils, with the Chester-Gleneig and Mt. Airy-Manor units (mostly residuum from saprolite) existing on the ridges and uplands and the Glenville and Codorus soils (mostly alluvium and colluvium) in the low regions and valley bottoms. Based on the engineering properties contained in the NRCS reports, the units described above would be either "potentially liquefiable" or "liquefiable" if the water content in the soils was sufficiently high.

Initial assumptions for the analysis include: (1) the general soil characteristics described above exist at all locations at the time of any large earthquake and the water table is sufficiently high that liquefaction/loss of strength would result and (2) liquefaction of soils beneath a roadway in flat topography would not result in any significant damage or otherwise compromise the evacuation route.

The region around Peach Bottom is generally flat to rolling topography with a relatively small number of streams and watercourses resulting in few bridges and overpasses. The general region of interest near the Peach Bottom site does not have a large number of locations where earthquake damage would render the evacuation routes nonfunctional. Information is not readily available on the specific engineered features of bridges and other infrastructure with which to make specific assessments on the likelihood of failure in a scenario earthquake. Therefore, it is assumed that: (1) all of the bridges across the Susquehanna River fail within 20 miles of the plant; and (2) the road across the Conowingo Dam would be unavailable.

6.5.2 Infrastructure Analysis

The seismic evaluation of the potential failure of roadway infrastructure identified 12 bridges and roadway segments that could fail under the postulated conditions.

Table 18 provides a brief description of each area assumed to fail, and Figure 73 shows the transportation network and the locations of the affected roadway segments and bridges.

Table 18 Description of the Potential Evacuation Failure Locations

Location	Description
A	PA Highway 372 upstream of Susquehanna River. Two single span bridges along a single roadway segment.
B	PA 372 bridge across the Susquehanna River north of the plant. Two lane multi span bridge.
C	US 222 Robert Fulton Highway. Two lane bridge, single span.
D	PA 74 (Delta- bypass/Pylesville Rd) south of Holtwood Rd (PA#372). Single span 2 lane bridge.

E	MD 136 - Whiteford Road. Two lane segment along lakeside. Potential for slumping into lake.
F	US 1 (Conowingo Rd) east of Susquehanna River and US #222. Two lane bridge, single span.
G	US 1 across Conowingo Dam. Two lane road.
H	US 1 west of Susquehanna River, west of MD #136. Two lane road, single span bridge.
I	MD 136 south of US #1. Two lane road, single span bridge.
J	MD 222 Susquehanna River Road north of Main St. Two lane road runs along river edge. Potential for slumping into river.
K	I-95. Six lane multi span bridge.
L	US 40. Four lane multi span bridge across Susquehanna River.

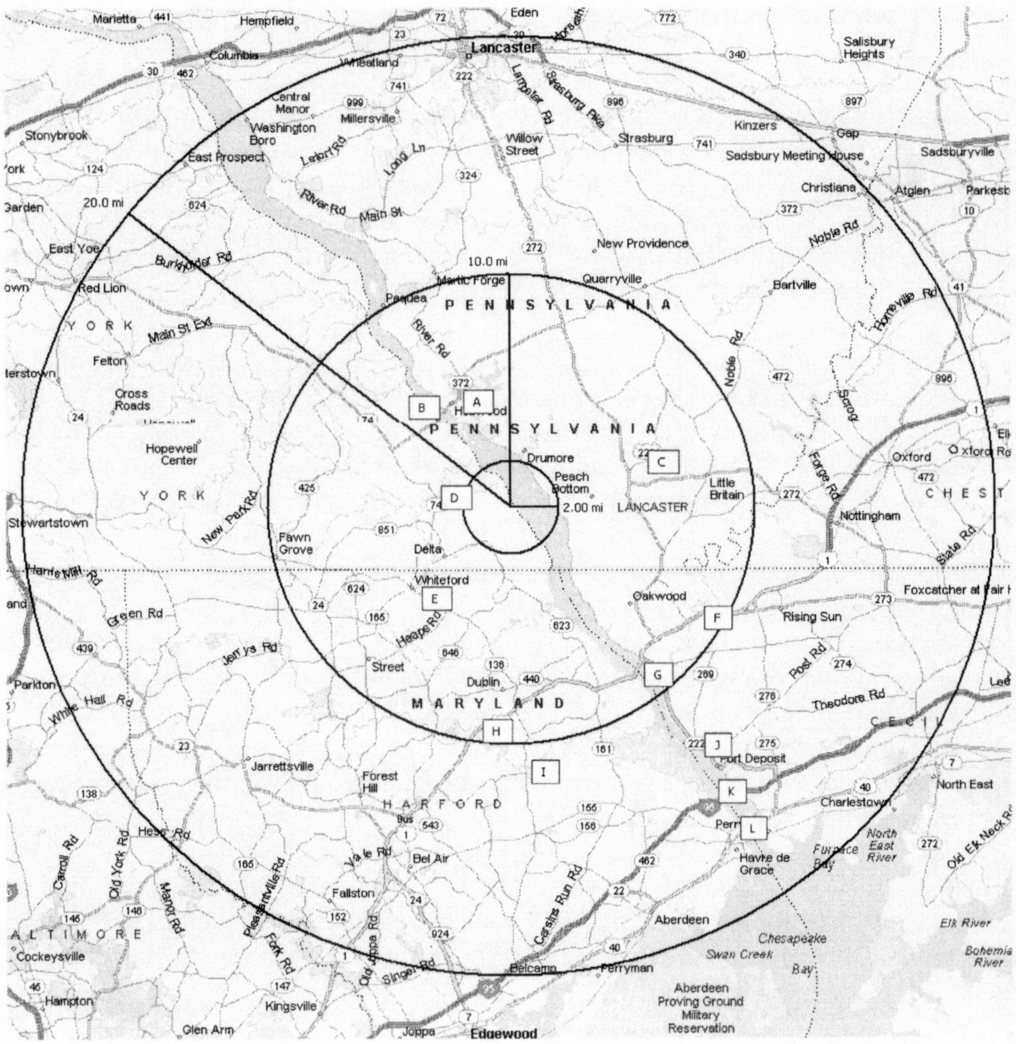


Figure 73 Roadway Network Identifying Potentially Affected Roadways and Bridges

Evacuations are planned and conducted to move the public radially away from the NPP. Evacuation routes are designated in emergency planning brochures, but all roadways within the EPZ serve the evacuees. Some of the bridges identified in the seismic analysis will have a negligible effect on the evacuation because of their location within the roadway network, while others may have a more pronounced effect.

The loss of bridges crossing the Susquehanna River does not affect the ETE. These bridges are represented as B, G, K, and L on Figure 73. The EPZ evacuation routes identified in the emergency plan indicate that evacuees west of the river would generally evacuate in a westerly or southerly direction, and evacuees east of the river would evacuate in a northerly or easterly direction. The only bridge (Bridge G) identified on a Peach Bottom evacuation route is U.S. 1 across the Conowingo Dam. Although this road is on the evacuation route map, the evacuation map indicates that travel west of the river would proceed westerly, and travel east of the river would proceed easterly; therefore, failure of the bridge would have no effect on the ETE.

Bridges A, C and D, in Figure 73, serve sparsely populated areas and have additional roads available, supporting a conclusion that evacuation delay because of loss of these bridges is minimal. Along Whiteford Road (location E on Figure 73) there is a potential for part of the roadway to slump into the lake. This is the only roadway failure in this area and there are many alternative routes north, west, and south of the location; therefore, no appreciable delay would be expected due to this failure. Travel along MD 136 may be diverted to multiple alternative roadways in the event the single span Bridge I fails.

Bridges H and I in Figure 73 are two lane single span bridges located south of the plan in an area where local roadways are available as alternate routes. PA 222 becomes MD 222 at the State line and may potentially slump off into the river at location J on Figure 73. As indicated on the map, there are alternatives to route around this area if the roadway does slump into the rive. Failure of these bridges should not appreciable affect the ETE.

The two bridges with the greatest potential to affect the ETE are F and H because they are located along the edge of the EPZ and serve larger areas. The total population identified in the ETE report for the area served by Bridge H is about 12,390. This equates to approximately 4,000 passenger cars using the vehicle population factor applied in the ETE report. For this volume of vehicles, only 800 vehicles per hour would need to exit the EPZ to stay within the 5 hour and 15 minute ETE. For one typical two lane roadway, a service volume of 1,700 passenger cars per hour may be achieved [29]. The alternate routes out of the EPZ have more than sufficient capacity to support the evacuating population.

The total population identified in the ETE report for the area served by Bridge F on U.S. is about 6,180, which equates to approximately 2,000 passenger cars. The Susquehanna River Road (PA 222) and a few local roadways nearby are available as alternate routes out of the EPZ, and no appreciable delay would be expected.

Based on review of the ETE report, the EPZ sub areas affected by loss of bridges, and a detailed review of the roadway network, a conclusion can be made that loss of the identified bridges will not increase the total ETE. This is consistent with the Peach Bottom ETE report which shows that evacuation of the northeast quadrant of the EPZ controls the evacuation time for the entire EPZ. Only Bridge B is located in this area, and it crosses the river as described above. Figure 74 shows an example of a bridge (US 222 Robert Fulton Highway) that could potentially fail under the earthquake conditions.

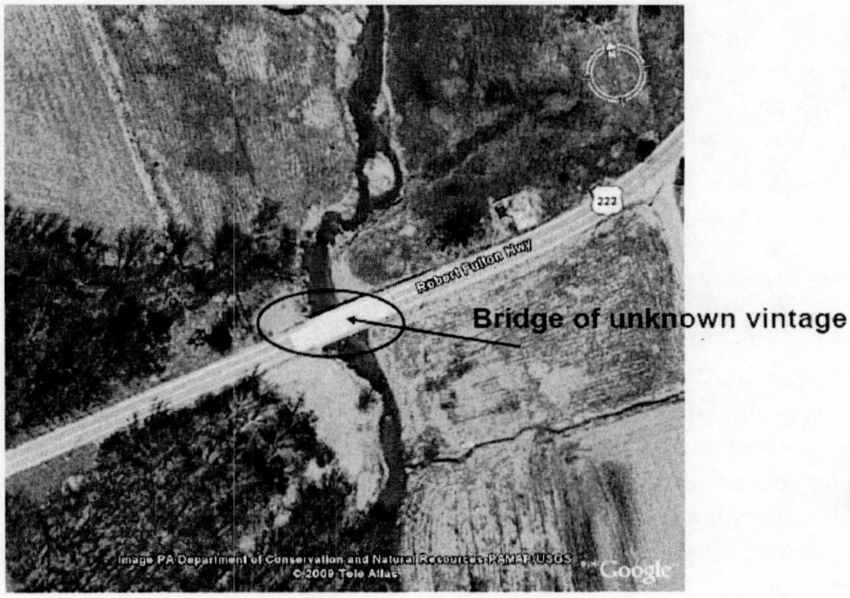


Figure 74 Bridge along Robert Fulton Highway

6.5.3 Electrical and Communications

The seismic event causes the loss of all onsite and offsite power which affects many aspects of a potential response. Typically, sirens would sound following declaration of an SAE and GE. The loss of power will affect the number of sirens that sound, however, it is expected many areas of the EPZ will not lose power. This has an effect on the initial alert and notification of the public, because loss of power limits the potential for some residents to receive instructions via EAS messaging. Televisions, household radios, and some telephones will not operate, although battery operated radios and car radios will. It is expected that the public will utilize these means of communications as well as societal forms, such as neighbor to neighbor propagating the EAS message throughout the EPZ. The alert and notification will be supplemented by route alerting, which is a planned backup form of communication for the EPZ.

The loss of power will cause traffic signals to default to a four-way stop mode, which is less efficient than signalization. Typically, emergency response personnel would respond to these intersections and direct traffic. A review of the roadway network within the EPZ indicates that there are only a few traffic signals and most intersections are controlled with stop signs. Table 7-1, "Recommended Traffic Control Management Locations," in the ETE report identified twelve key locations for emergency management traffic control to expedite traffic out of the EPZ [28]. As indicated in the ETE report, these twelve locations are included in the county plans. It is assumed that the OROs will be able to provide the twelve staff needed to support the few locations where traffic signals are not working; therefore, it is also concluded that the loss of signalization will not increase the total ETE.

The loss of power will affect traffic signals within the affected area, although this is not expected to be the entire EPZ. Typically, traffic signals default to red/red in a power outage requiring all directions to stop prior to entering an intersection. This effectively turns signalized intersections into four-way stop signs. Four-way stop, as an intersection control, is less effective signalization for moving large numbers of vehicles, particularly when traffic is present on multiple approaches [29]. The net effect within the Peach Bottom EPZ is minimal because there are very few signalized intersections within the area.

6.5.4 Emergency Response

The assumption on the event timing is a mid-week winter day in which the public is at work and children are at school. In Maryland, the primary shift of emergency responders would be on duty and immediately available at the time of the incident. Most of the Pennsylvania emergency responders are volunteers and would be at their normal place of employment. There is an initial need to assess damage and respond to life-threatening needs. These initial priorities for emergency response personnel may delay implementation of traffic control to support an evacuation. It is expected that responders will realize early that damage to local infrastructure is not severe and will focus efforts on communicating with the public via route alerting, where necessary. Route alerting would not be appreciably delayed because damage to local infrastructure is not severe.

During large scale emergencies, OROs routinely supplement staff with on-call and off-duty personnel. Although communications are assumed to be initially limited, radios are available to contact the needed staff, and off-duty responders may be expected to report for duty during such emergencies. By the time an evacuation is ordered, it is expected that OROs would have been augmented with additional staff. Because damage to infrastructure is limited within the EPZ, it is assumed that response personnel are available to support traffic control for an evacuation.

6.5.4.1 **Evacuation Time Estimate**

The evacuation times can be influenced if bridges fail, traffic signals do not operate effectively, and EAS messaging is not disseminated in a timely manner to inform evacuees of protective actions and preferred evacuation routes. Although there are a number of factors that can increase evacuation time, the effect on the ETE is expected to be limited because early in the event, emergency response personnel would begin route alerting and establish traffic control.

The roadway network beyond the EPZ was also evaluated to determine if loss of infrastructure might delay evacuees traveling through this area. How this loss of infrastructure affects the evacuation time is dependent more on the location of the facilities and the evacuating public that may be expected to use these routes. As described earlier, loss of the bridges and roadways identified in Table 18 are not expected to appreciably affect the ETE. This is due to the fact that only 12 locations were identified as potentially failing in a 20 mile radius around the plant, or 1,256 square miles. Within such a large area, there are many alternative routes for evacuation.

Another consideration in this analysis is that no large scale evacuation is expected for the 10 to 20 mile area. Therefore, the roadways are assumed to be substantially available to serve the evacuating public from the EPZ. Secondly, all of the bridges and the roadway section that are assumed to fail are located in the southern section of the 10 to 20 mile area beyond the EPZ. This area has a smaller population than the corresponding area to the north. OREMS was used to develop the ETE for the 10 to 20 mile area and results of the analysis demonstrated that longer evacuation times occurred in the northern section due to congestion experienced near Lancaster, Pennsylvania.

The ETE is used to develop the speeds for the evacuating public. The following ETEs provided for Peach Bottom were used for the base case analyses.

- 100 percent evacuation: 5 hours and 15 minutes; and
- 90 percent evacuation: 4 hours and 15 minutes.

These evacuation times were developed without consideration of impediments that might be experienced in an earthquake. For the seismic analysis, it is assumed that because this is a severe earthquake, the 0 to 10 shadow evacuation is increased from 20 percent used in the base case to 30 percent of the population. This effectively removes 30 percent of the total vehicles from the roadway network, which significantly reduces potential for traffic congestion. The wide availability of roadway infrastructure at these distances from the plant provides ample access for evacuees leaving the EPZ and should not appreciably effect evacuation times.

6.5.5 Development of WinMACCS parameters

Modeling the effects of seismic event required adjusting additional parameters. To account for the potential loss of bridges and roadway sections, the routing patterns in the WinMACCS model were adjusted to divert traffic around the locations identified by using routes not impacted by damaged bridges. This was completed for each grid element where an impacted roadway was encountered. Routing was manually adjusted to travel around rather than through the impacted grid elements.

The relocation parameters used in the earthquake analysis are the same as those used in the base case analysis.

Shielding factors are also the same as those used in the base case analyses. It may be expected that the damage to structures caused by an earthquake of this magnitude would include broken windows and some structural damage. Additionally, earthquakes frequently cause residents to go outside until they are more certain of the extent of structural damage that may have occurred. These factors would reduce the shielding capacity; however, because of the limited time that residents within the seismic area are assumed to shelter, no adjustments in the modeling were made. Although facilities are assumed to be structurally unsafe, the shielding values for the special facilities and tail were still applied consistent with the base case.

6.5.6 Seismic STSBO without RCIC Blackstart

The timing of emergency classification declarations for the STSBO without RCIC blackstart was based on the emergency action levels contained in site emergency plan implementing procedures. The timing of emergency classification declaration for the STSBO without RCIC blackstart was based on Table PBAPS 3-1 Emergency Action Level (EAL) Matrix contained in site emergency plan implementing procedures. The emergency classification timing was reviewed with the licensee for accuracy and this scenario is an immediate GE. With loss of offsite power and loss of DC power, operators cannot determine whether water level is above TAF, and a GE is declared based on EAL MG1. The emergency response timeline for the STSBO without RCIC blackstart scenario is shown in Figure 75. The duration of specific protective actions for each cohort are shown in Figure 76. Core damage, as evidenced by the first fuel cladding gap release, is calculated at 1 hour into the event, with a significant radioactive release from containment beginning 8 hours into the event as indicated by the containment failure.

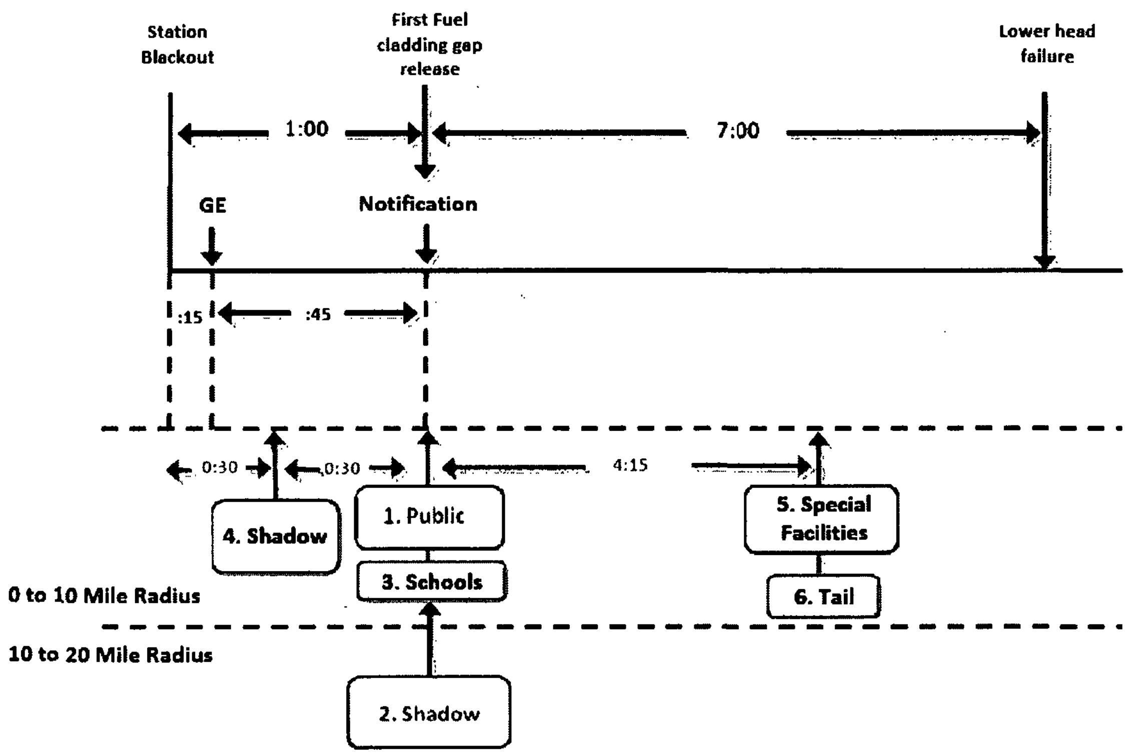


Figure 75 STSBO without RCIC Blackstart Emergency Response Timeline (Seismic Analysis)

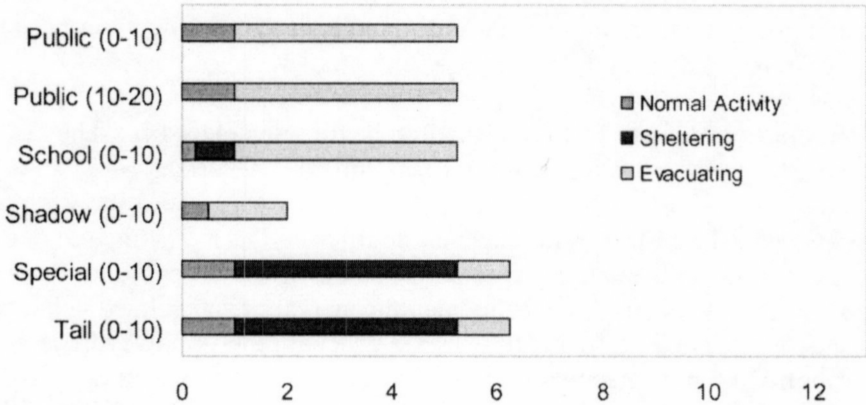


Figure 76 Protective Action Durations for STSBO without RCIC Blackstart (Seismic Analysis)

The timeline identifies points at which cohorts would receive instruction from OROs to implement protective actions. Cohorts would then implement the protective actions. Discussions were held with ORO and site representatives to help ensure SOARCA staff properly understand emergency response practices. While protective actions within the EPZ can be modeled in accordance with procedures, assumptions were made that approximate those actions that could be taken due to the effects of the earthquake. The evacuation is assumed to include the full EPZ which is consistent with emergency planning in Pennsylvania. For this analysis, a full evacuation was modeled assuming that the State of Maryland OROs would agree with the Pennsylvania protective action decisions.

It is assumed the large earthquake will be felt by everyone within the EPZ instilling a heightened preparedness. It is assumed the public is ready to respond to protective actions once they receive information, and some individuals will begin to prepare for an evacuation prior to receiving official notice.

Cohort 1: 0 to 10 Public. The 0 to 10 Public is assumed to begin evacuating upon receipt of notification which is provided primarily via route alerting. It is assumed that the effects of the earthquake are severe such that members of the public, knowing they live within an EPZ, begin preparations for evacuation shortly after the earthquake.

Cohort 2: 10 to 20 Shadow. This cohort is assumed to begin movement at the same time as the 0 to 10 Public once widespread media broadcasts are underway. It is assumed that the shadow population increases to 30 percent (from 20 percent for the base case calculations) of the public in the area beyond the EPZ.

Cohort 3: 0 to 10 Schools. Although communication systems may have been impacted, after receipt of the GE declaration, it is assumed that county emergency management agencies notify the schools promptly. Having felt the earthquake, it is also assumed that schools take the initiative to prepare to evacuate as they would for an emergency. Buses would be mobilized, and it is assumed schools begin evacuating about 1 hour after the start of the incident. The limited effect on infrastructure within the EPZ is not expected to appreciably delay bus mobilization. It is also assumed that given the magnitude of the earthquake, parents in the vicinity of the schools will pick up their children, reducing the need for a full complement of buses.

Cohort 4: 0 to 10 Shadow. This cohort is assumed to begin movement first. They experience the earthquake and quickly begin to evacuate avoiding the traffic congestion.

Cohort 5: 0 to 10 Special Facilities. The Special Facilities cohort is assumed to depart at the same time as the evacuation tail. Inbound lanes on roadways will be useable for emergency support vehicles, but localized congestion will delay the arrival of specialized vehicles. Special Facilities are assumed to leave at the same time as the evacuation tail; however, as discussed earlier, this is a simplification of the analysis because Special Facilities would realistically evacuate individually as resources are available.

Cohort 6: 0 to 10 Tail. The Tail takes longer to evacuate for many valid reasons such as the need to return home from work to evacuate with the family; the need to shut down farming or manufacturing operations prior to evacuating; and for the earthquake, the need to move rubble or other items prior to evacuating.

Cohort 7: Non-Evacuating Public. This cohort group represents the portion of the 0 to 10 public that may refuse to evacuate and is assumed to be 0.5 percent of the population.

Table 19 provides a summary of the evacuation timing for each cohort. In general, the cohorts in the seismic study have faster mobilization times and have the same evacuation speeds.

Table 19 Cohort Timing STSBO without RCIC Blackstart

Cohort	Delay to Shelter DLTSHL (hr)	Delay to Evacuation DLTEVA (hr)	DURBEG (hr)	DURMID (hr)	ESPEED[a] (early) mph	ESPEED[a] (mid) mph
0 to 10 Public	1.00	0.00	0.25	4.00	5	3
10 to 20 Shadow	1.00	0.00	0.25	4.00	5	3
0 to 10 Schools	0.25	0.75	0.25	4.00	5	3
0 to 10 Shadow	0.50	0.00	1.00	0.50	20	20
0 to 10 Special Facilities	1.00	4.25	0.50	0.50	3	20
0 to 10 Tail	1.00	4.25	0.50	0.50	3	20
Non-evac	0	0	0	0	0	0

[a] – 20 mph was used for the late phase evacuation speed for all cohorts.

6.6 Accident Response and Mitigation of Source Terms

The Peach Bottom SOARCA analyses, which reflected best-estimate thermal hydraulics and accident progression parameters, showed no offsite radiological consequences because all scenarios are mitigated by licensees through the use of safety and security enhancements, including SAMGs and10 CFR 50.54(hh) mitigation measures. Analyses were conducted of the consequences that may result if the onsite emergency response organization (ERO) takes no mitigative action other than to notify offsite authorities. The staff expects that mitigaticve actions would be attempted and that unmitigated variants are less likely. Furthermore, the assumption of no mitigative response does not comport with the realistic assumptions that have been used elsewhere in SOARCA. However, staff did not perform a human reliability assessment or a detailed seismic damage assessment for implementation of mitigative measures. The staff believed it appropriate to perform the sensitivity analysis to further understanding of core melt sequences, source term evolution and offsite response dynamics. To further support the expectation of mitigative response, a detailed discussion of the expansive resources available to support a national incident is provided below.

This analysis describes the likely national response to a severe nuclear plant accident and provides a basis for truncating the release no later than 48 hours after the accident begins. The discussion presents a timeline for bringing resources onto the Peach Bottom site in order to flood the reactor building to a level above a hypothetically melted core. Specific options are discussed but a number of additional efforts could be led by multiple organizations should it be necessary. The staff believes it is most likely that plant personnel would mitigate the accident before melt, but if efforts were unsuccessful the national level response would mitigate the source term.

The NRC has onsite inspectors that are available to provide first-hand knowledge of accident conditions. Concurrently, the NRC regional office would send a Site Team to the licensee's EOF to support the response. A Site Team would include reactor safety experts and protective measures experts to review actions taken to mitigate the accident and to review protective action decisions recommended to the public to assure that the most appropriate actions are taken. Although a Site Team would arrive after protective actions within the EPZ have been initiated, the Site Team would be available to support decisions on mitigation measures.

Peach Bottom is part of the Exelon fleet, which includes a remote EOF that would be activated and has access to fleet-wide emergency response personnel and equipment, including equipment from sister plants following 10 CFR 50.54(hh) reactor security requirements to mitigate the effects of large fires and explosions. Significant resources would be made available to the site to mitigate the accident. In addition to those directly involved in the incident and those agencies that fully test and exercise response plans, the Institute for Nuclear Power Operations and the Nuclear Energy Institute would activate their emergency response centers to assist the site. Knowledgeable personnel and an extensive array of equipment would be available and are considered in the decision to truncate the release at 48 hours.

The National Response Framework (NRF) establishes a coordinated response of national assets. Under established agreement, the DHS would be the coordinating agency[36] and NRC would be

[36] Coordinating Agency supports the Department of Homeland Security (DHS) incident management mission by providing the leadership, expertise, and authorities to implement critical and specific aspects of the response.

the primary cooperating agency[37] for an event in which a General Emergency is declared. Some of the other agencies cooperating in an incident include EPA, FEMA, HHS, and any other federal agency that may be needed. The assets of the Department of Energy (DOE) would be activated and brought to bear on the accident. The NRC has a extensive well trained and exercised emergency response capability that would support, and under unusual circumstances, direct licensee efforts. Communications systems require battery backup in accordance with 10 CFR 50.47 Appendix E, and multiple communication bridge lines would be established to facilitate structured communication among the various response teams. Satellite phones, cell phones, radios, and other means are available for those instances where communications have been affected.

6.6.1 External Resources

The primary focus of the site and utility ERO would be mitigating core damage, and state and local resources would focus on the public evacuation. However, it is typical, as demonstrated in drills and exercises, for EROs develop contingency plans in case initial onsite mitigative actions are not successful. The NRC ERO would focus on protection of the public and methods to reduce consequences reviewing the licensee and ORO information, actions, and decisions while performing independent analyses. If the site ERO is not successful with the onsite mitigative actions, as the sensitivity study assumes, various EROs would be considering in parallel the availability of portable power and pumping capacity from offsite locations. Portable generators of various sizes are available from dozens of providers within 100 miles of the site. Large portable generators could be ordered and brought into the site within the first 10 hours.

The initiating event for the reactor accident is a beyond design-basis earthquake close to the plant. This event causes significant ground motion and damage to certain types of structures, and bridges may not be passable, although most housing stock would likely survive the event. The six-lane I-95 and four-lane U.S. 40 bridges south of the Peach Bottom site cross the Susquehanna River. Loss of these bridges would have a limited effect on delivery of equipment because there are equipment suppliers on both sides of the river. Except as described in Section 6.5.2, roads would likely not be compromised as a result of the quake.

As indicated, it is expected that the roads would be passable; however, there is heavy airlift capacity in the region if needed. The Pennsylvania State National Guard air wing in Ft. Indiantown Gap, Pennsylvania, is less than 100 miles from the site. The air wing flies 25 helicopters (Chinook-47), each rated to lift about 26,000 pounds. Trailer mounted 600 kW generators weigh about 22,000 pounds and may be the largest generators that can be airlifted to the site in a timely manner. These generators are large enough to support many onsite power equiptment, including pumps. The air wing Public Information Officer confirmed that there are typically 5 to 25 operational helicopters available. If this air wing were not available, there are others in the Mid-Atlantic region. Given national response to a General Emergency, heavy lift helicopters would be made available if requested within about 12 hours. A source of electrical

[37] Cooperating Agency are those entities that have specific expertise and capabilities to assist the coordinating agency in executing incident-related tasks or processes.

generators would already have been located and arrangements made for obtaining one or more. It is estimated that the largest generator(s) could be airlifted onsite and be operational within about 20 hours. If smaller generators were useful, they would be more readily available. All times discussed above are from start of accident.

6.6.2 Mitigation Strategies

Team members of the site ERO, utility ERO, and NRC ERO are responsible for identifying methods to maintain core cooling and would focus on injecting water into the vessel. For events such as these, the mitigative measures identified in the Severe Accident Management Plan is to direct primary containment flooding. This action would provide a scrubbing of the source term and would reduce any further release. Covering the core debris on the drywell floor would truncate the fission product aerosol release to the environment because the overlying water would cool the debris and scrub any fission product releases from the debris. Although a fraction of the degraded core may remain in-vessel, this is unlikely to lead to substantive offsite releases to the environment for the following reasons:

- Potential injection paths for containment flooding include core spray and drywell spray. Use of either of these paths would provide water spray to cool any core debris remaining in-vessel and scrub any release of radioactive aerosols from that debris.
- Core debris remaining in-vessel may be too cold to release fission product aerosols, because it did not heat up and relocate down into the RPV lower plenum.
- Any release from core debris remaining in-vessel would have to go through the hole in the drywell shell at the bottom edge of the vent pipe and would be scrubbed by the water covering the hole.
- Although the drywell head may have lifted as a result of containment pressurization during the time period between RPV failure and liner melt-through, it is expected to reseat after lifting because the head bolt material is in the elastic range.

After the release begins, the site would be contaminated and working conditions are more difficult. However, the plant staff is trained in radiological work, and they are supported by a full staff of health physics technicians. Staff from Exelon fleet plants could be at the site beginning very early with technical experts responding as needed. Nuclear power plant expertise would be available and obtained from neighboring plants in the event that such resources were needed.

An approach to achieve flooding og the Reactor Building lower elevations that may be feaseable would be to direct fire hose streams through the open truck bay doors resulting in the water entering the Torus room through the open grating at elevation 135 of the Reactor Building. This would avoid the need to rely on Core Spray pumps and to enter the building to align the Core Spray systems valves. Initially, pumper trucks from off-site fire fighting agencies could be used to spray water into the building. Materials are staged onsite to control radiological runoff from a 10 CFR 50.54(hh) event that could be used to promote water flowing into the lower elevations, rather than draining out the open doorway. A monitor nozzle could be used on one of the hose lines set on the fog spray mode of operation to provide scrubbing of the release as it progressed from the Torus room up through the open equipment hatches in the vicinity of the truck bay. Pumper trucks from the local fire departments who normally respond to requests for assistance from the station each have a 1000 gpm pump and most are 1250 to 1500 gpm. As additional offsite resources become available, larger pumps could be brought.

Additional pumping capacity to move river water to the site could be performed by fire trucks. Based on the proximity of these resources, these vehicles could traverse potentially affected roadways and be on site within a few hours and would begin operations within 6 hours. If roads are not passable, transportation is more difficult and the use of helicopters would be necessary. The site ERO would work with the State to identify local resources and pumping capacity that could be airlifted onto the site in approximately the same 20 hours assumed for electrical generation equipment. It may necessary to bring several pumps to the site to feed core spray pumps at capacity. The site ERO would have been working on using this pump to inject water soon after power was lost.

The site ERO, supported by the utility and the NRC, would be considering other measures in case core spray proved to be unavailable. These personnel know the plant well and may identify innovative solutions. Use of the containment vent was considered in this analysis. The vent exits the reactor building and has shielded manual isolation valves. This system could be cut open and quickly modified by the site staff of experienced machinists and welders to accept fire truck hose or other pump connections. This may affect pumping capacity dependent on the manner of ganging portable pumps and the fire-system diesel-driven pump. The size of the line is 16 inches and would not limit capacity; however, the structural supports for containment venting pipe are not structurally designed for piping filled with water. The site ERO would work these efforts in parallel and could be ready for operation in about the same 12 hours as other methods.

6.7 Emergency Preparedness Summary and Conclusions

Advancements in consequence modeling provide an opportunity to integrate realism in the implementation of protective action decisions applied for discrete population segments. To best utilize these advancements, detailed information was developed from area information and obtained from OROs. Through a user interface added to the model, this detailed information was input to reflect differences in the implementation of protective actions by various population segments. These advancements are significant because they now allow the modeling of response activities, timing of decisions, and implementation of protective actions across different population segments. Previous consequence analyses, such as Sample Problem A [24], NUREG-1150 [9], and NUREG-6953 Volume 1 [20], typically used a single cohort to represent the EPZ public and considered a non-evacuating cohort. For the first time, consequence modeling can represent the actions of OROs and the timing of multiple sectors of public response with a defensible basis provided for the timing of these actions.

Response parameters were developed using site specific information and local data. The Peach Bottom EALs were obtained for each of the accident scenarios modeled to best reflect the timing of the declaration of SAE and GE. Because a station blackout is the initiator for three of the scenarios, the timing of these declarations was identical. For each of the accident scenarios, the specific EAL information and cohort movement were applied, and the WinMACCS files were compiled for the consequence analysis. The ETE provide detailed information regarding the evacuation of the general public, schools, special facilities, and the evacuation tail.

To provide a brief comparison, NUREG-1150 established a single cohort to represent the population within the EPZ that evacuates. A second cohort was established to represent a non-evacuating cohort and was 0.5 percent of the population, which is the same value used in SOARCA. In the NUREG-1150 analysis, the EPZ population was first sheltered and then evacuated as a single group at one speed. The population outside the EPZ did not evacuate and no shadow evacuation was treated.

In the SOARCA analysis of Peach bottom, six cohorts were modeled for each of the accident scenarios and a seventh cohort was added for the seismic analysis. Response timing and sheilding factors were developed for each specific cohort.

- For the general public, shielding factors appropriate for the region were applied during normal, sheltering, and evacuation times and speeds were derived from the Peach Bottom ETE.
- Schools are notified directly in accordance with offsite emergency response plans and buses mobilized to support expedited evacuation of schoolchildren.
- Special facilities are notified early, but respond differently than schools because of the need to mobilize specialized transportation resources including wheelchair vans and ambulances. Evacuation of these facilities in practice, would be on a facility by facility basis as resources become available. In SOARCA, these facilities were modeled as evacuating at the same time after an extended sheltering period. The shielding protection values for these facilities are better than those for standard housing.
- The evacuation tail includes those members of the public who take longer to evacuate and are the last to leave the area. Indoor shielding values were applied to this cohort and they were evacuated late in the emergency moving at faster speeds because of the lower volume of traffic on the roadways at this time. The timing of the evacuation tail was derived from the ETE as the time at which the last 10 percent of the public begin to evacuate.
- A shadow evacuation cohort was established to represent a portion of the public that evacuates although they are not under an official evacuation order. Recent data published by the NRC [30] provide a quantitative value of the shadow evacuation.
- A non-evacuation cohort representing 0.5 percent of the population was included in the analysis. Normal shielding values were applied to this cohort.
- For the seismic analysis, it was assumed that a shadow evacuation of residents from within the EPZ occurs prior to the issuance of an evacuation order. This additional shadow evacuation cohort was included in the analysis.

Three sensitivity analyses were performed to assess effects expanding the limits of the evacuation and a delay in implementation of protective actions. The sensitivity analyses were performed using the STSBO without Blackstart scenario because this has an earlier release than other scenarios. In the first two sensitivity analyses, the limits of the evacuation were extended to 16 miles and 20 miles. An ETE was developed using OREMS to establish evacuation response parameters for the consequence model. The peer review committee suggested the sensitivity of the response timing be evaluated. This third sensitivity analysis was conducted maintaining all of the base case parameters and increasing the delay of response actions by 30 minutes.

An analysis of the effects of a seismic event was completed and showed that at the Peach Bottom site, there are relatively few roadway sections and bridges that may fail. The roadway sections and bridges that might fail were dispersed enough that local traffic would be able to detour around these areas and exit the affected area. As a result, the timing parameters (e.g., notification) for the offsite response agencies are not delayed. The analysis showed that because the public is immediately aware of the seismic event, having felt the effects of the earthquake, they mobilize more quickly and when notification to evacuate is received, they are prepared and respond promptly. As a result, general timing of the response occurs more quickly because the delay to evacuation is reduced while the travel time is about the same.

The Peach Bottom SOARCA analyses, which reflected best-estimate thermal hydraulics and accident progression parameters, showed all scenarios are mitigated by licensees through the implementation of proceduralized mitigation measures. The staff expects that these mitigative actions would be attempted. Staff also evaluated the availability of offsite support that could also be used in mitigation efforts. The truncation evaluation describes some of the types of resources, potential response times, and conceptual approaches that might be considered to further mitigate an accident, but does not attempt to identify or fully quantify the mitigation efforts. The quantified mitigation results are developed in the MELCOR analysis.

The parameters developed for the base case and sensitivity analyses provide input to the MACCS2 consequence model presented in Section 7.0.

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