RBR Consultants, Inc.

Critique of "Chernobyl on the Hudson?"

Executive Summary

"Chernobyl on the Hudson?" (COH) by Dr. Edwin S. Lyman displays such an extensive collection of inaccuracies, inadequacies, absurdities, and misrepresentations that it has no social or scientific merit. It has no place in any legal proceeding and all contentions that incorporate or refer to this report should be rejected.

As will be shown below, inaccuracies, inadequacies, absurdities, or misrepresentations appear in virtually every step of the COH analysis from the initial assumed air attack on Indian Point to its final highly senationalized health and economic consequences. Instead of up to 44,000 near term deaths, correctly analyzing Lyman's scenario would result in effectively zero near term deaths. Instead of up to 518,000 cancer deaths as Lyman claims, a figure of about 200 to 400 is more probable, even assuming that his highly unlikely terrorist scenario actually succeeded. Instead of up to 2.1 trillion dollars in economic losses, a more realistic figure is $20 to $40 billion dollars. Offsite economic consequences from nuclear accidents at Indian Point, not terrorist events, were not analyzed here but would have releases of radioactive material on average about ten times smaller than terrorist events, so even smaller consequences are expected. Instead of an early fatality risk with a range of 18 miles, this range would be close to zero for a buoyant plume that would arise from an airplane crash on the containment building and about one mile for a non buoyant plume for other types of postulated terrorist events, at the 95th percentile weather condition. These much smaller figures are partly derived from independent analyses, comments by other interveners and a review of the Chernobyl accident, <u>but mostly derived by comparing Lyman's COH to other reports Lyman has co-authored and inconsistencies within COH.</u>

The decision to extend or not to extend the licenses of Indian Points 2 and 3 is of great significance to the New York area and has national implications. As such, good governance requires that this decision be based on the consideration of both probabilities and consequences, i.e., a decision based on comparing of the economic and health <u>risks</u> and benefits of continued operation versus the economic and health <u>risks</u> and benefits of terminating the operation of these plants. COH fails to provide a <u>risk</u> basis for effective government decision making because it is exclusively concerned with consequences. Even if COH did not have all these inaccuracies, inadequacies, absurdities, and misrepresentations, without considering the probabilities of these claimed consequences COH would still fall far short of what is necessary to make decisions of this magnitude.

If "Chernobyl on the Hudson? is a question about Indian Point, then the answer is a resounding 'No!".

1.0 Historical Perspective

COH is yet another in a series of exaggerated claims about consequences from releases of radioactive material from nuclear power plants. Such misrepresentations have been going on for decades (reference [1]). James Lee Witt, former Director of FEMA, in his January, 2003 draft report "Review of Emergency Preparedness at Indian Point and Millstone" warned that advocacy groups were still misusing 1982 NRC data "In fact, some advocacy groups should bear responsibility for the potential consequences of public misperceptions. For example, in pursuit of their agenda to close Indian Point, some have misused NRC data (See Limitations and Omissions section for a discussion of CRAC-2), presumably to frighten and alarm the public. Misuse of information can lead to behavior that may endanger public health and safety" (reference [2]). Witt goes on to identify Riverkeeper, who commissioned COH, as an advocacy group.The Witt warning appears to have gone unheeded. Advocacy groups and New York State have submitted contentions where huge potential offsite consequences are claimed, but have apparently done this without an independent and competent review of the accuracy of these postulated consequences, i.e., they have not heeded Witt's warning.

Dire, but untrue, statements about offsite consequences were reported following the accident at the Three Mile Island nuclear plant where there was essentially no release of radioactive material into the environment. Similarly, huge long term health consequences were postulated following the accident at Chernobyl. Yet, as reported in 2006 by the World Health Organization (WHO) in its twenty year retrospective on the health effects of the Chernobyl accident, "The estimates point to a total of several thousand deaths over the next 70 years, a number that will be indiscernible from the background of overall deaths in the large population group. The estimates do not substantiate earlier claims that tens or even hundreds of thousands of deaths will be caused by radiation exposures from the Chernobyl accident" (reference [3]). More specifically, WHO estimates that "4000 casualties may occur over the lifetime of about 600,000 people under consideration. As about a quarter of them will eventually die from spontaneous cancer not caused by Chernobyl radiation, the radiation induced increase of about 3% will be difficult to observe" (reference [4]). Since one quarter of the above projected casualties are not attributable to Chernobyl, the estimate for the general public from this accident is about 3000.

In addition to the Witt and WHO comments, other warnings have gone unheeded. Another case of exaggerated nuclear plant consequences appears in the Alvarez report (reference [5]) in which Dr. Lyman is a co-author. The Alvarez/Lyman report is concerned with possible terrorist attacks on spent fuel pools. They postulated extreme consequences, up to 250,000 cancer deaths. The Alvarez/Lyman report was widely broadcast in an article by Matt Wald of the NY Times. This Alvarez/Lyman report also was referenced in Proposed Resolution 64-A by New York City Council's Committee on Environmental Protection which called for the shutdown of the Indian Point plants. Lyman testified before this NY City Committee in a hearing on Proposed Resolution 64-A. The consequences claimed in the Alvarez/Lyman report were so alarming that members of the U.S. Congress referred it to the National Academy of Sciences (NAS) for an independent review.

Alvarez, Lyman and their co-authors advocated that nuclear power plants across the United States be modified by removing 80% of the spent fuel from their pools and placing them into on-site casks over a period of ten years at a cost of several billion dollars. This major rearrangement of the spent fuel pools was not supported by the NAS, leaving any such rearrangement to be determined by a cost/benefit analysis. Neither Alvarez nor Lyman nor other co-authors have produced a convincing cost/benefit analysis to date that would justify their proposed rearrangement.

The NAS did recommend a more favorable way to reconfigure the fuel in the spent fuel pools, based largely on presentations made by the Nuclear Regulatory Commission and heat transfer analyses by a consultant sponsored by Entergy, "Additionally, the committee received a briefing from Entergy Corp. staff and its consultants under contract to analyze and understand the consequences of a loss-of-pool-coolant event in a spent fuel pool in a PWR plant" (reference [6]). This NAS reconfiguration did not require any spent fuel to be placed in casks. Entergy has rearranged its spent fuel according to the NAS recommendation. Entergy also invited the NAS to inspect the Indian Point spent fuel pools, which they did. One of the important conclusions reached by the NAS and published in their report is that "The second measure *(water spray systems*) would probably be more expensive to implement and may not be needed in all plants, particularly plants in which spent fuel pools are located below grade or are protected from external line-of -sight attacks by exterior walls and other structures" (reference [7]).The NAS recognized that certain designs, such as Indian Point with its spent fuel pool below grade, inherently offer greater protection against threats by terrorists. In its original design, and later by plant operation, the Indian Point facility has minimized the threat of terrorism. Entergy has been an industry leader in this area by sponsoring specific heat transfer analyses of spent fuel accidents, by inviting the NAS inspect the Indian Point facility, and by implementing applicable NAS recommendations.

The fact that NAS did not to support the Alvarez/Lyman proposal in spite of their claimed enormous potential consequences should have been another warning to all to examine Lyman's COH with caution. In fact, testimony provided by Dr. Gordon Thompson, another intervener and also a co-author of the Alvarez paper, points out that the Alvarez/Lyman spent fuel pool "fix" would be unsafe if residual water or debris were present in the base of the pool (reference [8]). Similar conclusions were provided by Mr. Herschel Specter of RBR Consultants, Inc. who provided testimony at the NAS public hearings and presented his analyses in a paper at an international nuclear safety meeting (reference [9]).

Not only were these earlier warnings unheeded, other ones should have been issued, but likely were not. It was pointed out by a critic of the Alvarez/Lyman report that a simple "sanity check" of the population at risk had not performed. As a result, these authors assumed an at- risk population of about twice that of the whole United States, clearly an impossibility. Just correcting this one error was sufficient to reduce the calculated number of latent fatalities in the Alvarez/Lyman paper by a <u>factor of 44</u>. Lyman and two of the original authors <u>quietly</u> published their corrected values in an addendum to the Alvarez/Lyman report in "Science and Global Security" (reference [10]), but not in the NY Times. Members of Congress, The New York City Council, NY State, the Attorney General of Connecticut, Westchester County, and Riverkeeper likely were never warned by Lyman of this gross error.

Then came Lyman's COH with its claim of up to 44,000 near term deaths, up to 518,000 cancer deaths and up to 2.1 trillion dollars worth of damage. In spite of the extreme consequences claimed by Lyman in his COH and a full page advertisement of it in the NY Times by Riverkeeper, no one turned to the NAS for an independent assessment. Independent assessments by the NAS on Indian Point issues have been done twice: the Alvarez/Lyman report on spent fuel pools and, more recently, on economic issues that would arise from the shutting down the Indian Point reactors (reference [11]). Since COH was published in September 2004, ample time was available for the NAS to examine COH prior to any advocacy group or NY State submitting contentions based on it. Most likely the NAS would have uncovered many of the same defects in COH that are identified here. With the results of such an NAS review present contentions might have excluded such an alarmist report. What is all the more remarkable is that the extreme consequences of Lyman's COH are even larger than those claimed in the earlier Alvarez/Lyman report, yet there was no call for an independent review. This lack of an independent review did not deter New York State from referring to COH in its Contention 27, part 15. Warnings about claims of extreme consequences have gone unheeded and an opportunity to have a timely, competent, and independent review of COH by the NAS has been lost.

Lyman's "Chernobyl on the Hudson?" is the type of activity that James Lee Witt has warned about, with an updated version of the 1982 sensationalism.

2.0 More Realistic Analyses

There is an important connection between the obscurely published Alvarez/Lyman addendum and Lyman's COH. In the addendum the number of calculated cancer fatalities from a 3.5 megacurie (3.5 million curies) release of radioactive cesium, 137Cs, from an Indian Point spent fuel pool[1] is 1500 people. In Lyman's COH the peak number of cancer deaths is as many as 518,000, some 345 times larger than the figure in the addendum, even though both reports had postulated releases of cesium that are almost the same size (3.5 megacuries of 137Cs), use the same nuclear power plant site, were published in a similar time frame and have Lyman as an author. Even Lyman's COH mean consequence number of latent fatalities, 28,100, is some 19 times larger than a similar release in Lyman's addendum. Lyman attempts to justify these vastly different results between his addendum and COH consequences by claiming that they are mostly the result of different plume buoyancies. The plume in COH was assumed to be "cold", i.e., non buoyant, whereas the spent fuel pool fires analyzed in the addendum created a "hot" buoyant plume. "Cold" plumes remain near the ground and can result in greater exposures to radiation than buoyant plumes. Therefore much rests on the issue of plume buoyancy.

However, Lyman's buoyancy explanation fails because his scenario is based on the crash of a large airplane into one of the containment buildings at Indian Point. Burning jet fuel from the airplane crash would itself result in a heated plume and this is ignored in Lyman's COH analysis. Ignoring the importance of this jet fuel is in conflict with the Alvarez/Lyman report (reference [12]) which reported that the heat from burning the jet fuel from an aircraft would be so large that it would be enough to evaporate about 165 tons of water. So Lyman's COH report is in conflict with both Lyman's addendum and with the Alvarez/Lyman report, i.e., Lyman vs.Lyman and Lyman. More information about jet fuel fires is provided in Section 6, below.

As explained below, Lyman's assumed release of about 3.5 megacuries of radioactive cesium is based on an invalid use of an NRC report, NUREG-1465 (reference [13]). Proper source term analyses that use NUREG-1465's removal processes result in a much smaller release to the envi-

1 See TABLE A-1 in the appendix.

ronment, in the neighborhood of 0.5 to 1.0 megacuries of radioactive cesium (reference [14]), even for successful terrorist scenarios. Using Lyman's addendum, but accounting for plume buoyancy caused by jet fuel fires from this airplane crash and correcting for Lyman's misuse of NUREG-1465 by using an appropriately smaller cesium release, the estimated number of latent fatalities is about a thousand times smaller, in the range of about 200 to 600 for this highly improbable event. The appendix provides the basis of these much smaller numbers.

To put this in perspective, if this hypothetical radioactive plume had a range of 50 miles from Indian Point (reference [15]) the expected number of cancer fatalities over time from natural background causes is about 3.7 million, but with a probability of close to 1.0. This very small ratio of 200 to 600 projected nuclear caused latent cancer fatalities to normal background cancer fatalities of 3.7 million is consistent with the World Health Organization's review of Chernobyl's long term health consequences "a number that will be indiscernible from the background of overall deaths in the large population group." Plume buoyancy would also eliminate the risk of any near term deaths, i.e., early fatalities. In fact, no member of the Russian general public died of acute radiation syndrome from Chernobyl, even though they did not evacuate. The heated plume at Chernobyl was sufficient to lower local airborne concentrations below that needed to cause an early fatality among the general public. The 28 early fatalities at Chernobyl were limited to people who either went on site or flew in a helicopter through an intense portion of the radioactive plume. Other studies (reference [16]) of postulated terrorist events at Indian Point, but with realistic source terms, show a near zero risk of becoming an early fatality, even if the plume were unheated.

Calculated offsite economic consequences from an assumed successful terrorist attack would also be far smaller[2], in the range of $20 to $50 billion, based on Lyman's own conservative addendum (reference [17]) that relates offsite costs to the number of megacuries of released cesium and use of a more realistic release of cesium in the neighborhood of 0.5 to 1.0 megacuries. If Lyman's monodirectional plume model were replaced by a more realistic treatment of meteorology which accounted for shifting wind directions, calculated offsite economic consequences would be smaller than $20 to $50 billion. The economic consequences of releases of radioactive cesium from an accident at Indian Point, rather than a terrorist event, were not analyzed here. Such releases are not expected to be buoyant, however their frequency weighted cesium release fractions are about a tenth of those from independently analyzed terrorist events at Indian Point (reference [18]).

2 See Section 10.2.3 in the appendix.

3.0 Chernobyl versus Indian Point

3.1 Introduction

Lyman's provocative title "Chernobyl on the Hudson?" attempts to equate Indian Point with Chernobyl. In fact their designs and operation are opposites. The Chernobyl design would never have been licensed in the United States or in most other countries.

3.2 Design Differences

One of the most important design faults at Chernobyl was that the plant did not have a meaningful containment system. It had a "confinement" system that was only capable of withstanding small pressure increases. As a result of this when significant steam releases from the damaged reactor entered this building it blew it apart and the fuel channels attached to it, thereby creating a direct pathway between the reactor core and the outside environment. A second very important design fault was the "physics" design of Chernobyl. The "physics" of this design was such that when cooling water was lost here was a very rapid and large increase in power level. This power excursion destroyed the reactor, the confinement building, and exposed the very hot graphite in the reactor core to air, causing the graphite to catch fire. This added chemical energy to the energy being generated by the power excursion. This led to various explosions and a rapid release of radioactive material into the environment where a thermally hot plume was lofted high into the atmosphere.

By contrast, the Indian Point containments are among the strongest containment buildings in the United States. These reinforced concrete buildings have large free volumes of 2.6 million cubic feet and high failure pressures (approximately 141 psia), about 250 percent greater than their design pressures. The combination of large free volumes and high failure pressures means that these containment buildings are capable of absorbing large quantities of energy before failure pressures might be reached. If a core melt were to occur and no mitigative actions were taken, it would take more than 20 hours to reach the containment failure pressure. The very large energy absorption capability of these containments also means that pressure spikes during the core melt process, hydrogen explosions and steam explosions, if any, are very unlikely to lead to a loss of containment integrity. If either of two containment spray systems is turned on, the release of significant amounts of radioactive material to the environment is precluded. Other accident scenarios where the containment might be bypassed have been shown to be extremely unlikely.

3.3 Fast Breaking Accidents

A fast breaking accident might be defined as an event that causes the radioactive material to leave its normal design location in the fuel and enter the environment shortly after that. Chernobyl's two very important design flaws: a reactor physics design that resulted in a power excursion upon loss of cooling water and a very limited confinement system, led to a fast breaking accident.

Each Indian Point plant is designed so that upon loss of cooling water the plant automatically shuts down and power levels rapidly drop to about one percent of full power. This rapid decrease in power level would be achieved without engineered safety features; it would just be a result of the plant's reactor physics. Even if there were a core melt, this reduced power level plus the very large heat capacity of the reactor core, the surrounding reactor vessel and its internals, would result in a comparatively long time before to the onset of a release to the environment. The shortest time at Indian Point 3 from the start of a core melt sequence to a release of radioactive material to the environment from a containment bypass sequence is 2.6 hours, based on the Indian Point Probabilistic Safety Analysis (PSA). Other analyses performed for Entergy depicting a terrorist scenario with an immediate failure of the containment, followed by the initiation of a core melt sequence just 30 minutes later, still required another 2.2 hours to reach the onset of a release. Even Lyman's COH presentation is not a fast breaking accident since 1.8 hours is given as the time between the initiation of a core melt sequence and the onset of a release to the environment (reference [19]). Further, these events not only take a few hours to reach the onset of a release, these releases would stretch out over many hours. These are not fast breaking accidents.

A stark difference between Chernobyl and Indian Point is that Chernobyl experienced a fast breaking accident whereas the Indian Point design precludes this type of event. Realizing that fast breaking accidents are precluded at Indian Point discredits New York State's Contention 29 and associated testimony presented by Mr. Raymond C. Williams in Volume 2 of the New York State documentation which is based on the assumption of a fast breaking accident at Indian Point.

4.0 Lyman's Air Crash

4.1 Introduction

Lyman assumes that a large aircraft has been hijacked in spite of all the post 9/11 efforts to prevent this. He then speculates that these terrorists ignore all nearby soft targets like the gasoline refineries in New Jersey, Yankee or Shea stadium on a game day, skyscrapers, Grand Central Station, famous landmarks, Kensico Dam which is on higher ground above White Plains, New York, water treatment and other facilities with large amounts of chlorine in them, the 81 sites in New York, New Jersey and Connecticut, each if which has over 100,000 pounds of extremely hazardous substances in them (reference [20]), and many other largely unprotected soft targets. Instead, these terrorists head towards Indian Point, one of the most hardened sites in the country with the mistaken notion that the release of radioactive material might cause the extreme consequences. Lyman then postulates that these terrorists fly over to the Indian Point site and manage to crash into one of the containment buildings. Even fellow intervener, Dr.Gordon Thompson, questions this assumption (reference [21]). "The staff made the mistaken assumption that large, fuel-laden aircraft would pose the greatest threat using this attack mode. Large, commercial aircraft caused major damage to the World Trade Center and the Pentagon in September, 2001, but they would not be optimal as instruments of attack on a nuclear power plant. They are comparatively soft objects containing a few hard structures like turbine shafts. They can be difficult to guide precisely at low speed and altitude."

4.2 Further Requirements

Lyman takes this less than optimal instrument of attack and imposes some very difficult additional requirements on the terrorists. His first objective is eliminate all sources of offsite and onsite electrical power. So the actions of the terrorists in the hijacked plane would have to be co-coordinated with terrorists on the ground who would have to destroy that portion of the electrical grid that supplies electricity to Indian Point. If all sources of onsite and offsite electrical power can be made inoperable then the containment sprays would not work. This is necessary for Lyman to claim such huge consequences. If either of the Indian Point containment sprays worked the offsite releases of radioactive material would be negligible even with a breached containment and a core meltdown. Loss of all electric power would also render the emergency core cooling system inoperable.

Lyman then assumes that the aircrash was so powerful that shock waves were sent throughout the containment structure which, in turn, were strong enough to disable the onsite emergency diesel electric generators. However, these emergency electric generators are housed in structures designed to withstand the design basis earthquake, and the effects of huge hurricanes and violent tornados. Further, these emergency diesel electric generators (EDGs) are subjected to periodic severe testing where they most go from low speeds to full power in a few seconds. So by design, and then demonstrated by testing, these EDGs are capable of withstanding a wide range of vibrational forces. Lyman does not offer any plant specific analysis that would demonstrate that airplane impacts would be sufficient to cause Indian Point's EDGs to become inoperable and remain inoperable. Lyman also ignored non-electric means at Indian Point that can provide for core cooling. The EDGs and the non-electric means of core cooling are located in different places making it even more improbable that a single shock wave would render all of this equipment at different locations inoperable. Add to this the complexity of the non-uniformity of the Indian Point containment structure itself, with its 3 foot thick reinforced concrete dome above the springline and four feet thick cylindrical walls below it. The variable thickness of the containment building and the different locations of structures that house the EDGs and the non-electric core cooling equipment may present a very difficult, if not impossible, challenge for terrorists to determine the precise speed of the aircraft and the location on the containment surface that would match Lyman's description of how to eliminate Indian Point's onsite core cooling capabilities. Even if the exact aircraft speed and precise location on the surface of the containment building could be determined beforehand, it is unknown if the terrorists could control the aircraft with sufficient precision to achieve their mission.

If this task weren't already difficult enough, Lyman then imposes yet another requirement on these terrorists. They are to strike the containment building, but not to breach it (assuming that they could). They are to weaken the containment structure so that at a later time when there is a pressure spike in the containment this weakened area will give way. Since the containment would be pressurized at this time, the atmosphere in the containment will rapidly depressurize in 216 seconds. Lyman claims that this would sweep all of the radioactive content in the containment into the environment. Lyman pursues the mistaken idea that a rapid depressurization of the containment would lead to large environmental source terms. This hypothesis is shown to be inaccurate, as discussed in Section 6 below.

The aircraft strike should not be so hard that it breaches the containment immediately. This would prevent a later rapid depressurization when the bottom head of the reactor vessel melts and falls in the water in the cavity below it producing a pressure spike which, according to Lyman, causes the weakened containment area to pop open. However, the aircraft strike shouldn't be too soft because Lyman wants the shock waves to be strong enough to cause the loss of all onsite sources of emergency power and non-electric ways to cool the reactor core and initiate a loss of coolant core melt sequence. The crash should not be “too soft” or “too hard”, but “just right”. Lyman has invented the Goldilocks aircrash of nuclear terrorism.

5.0 Lyman’s Source Terms

5.1 Introduction

Lyman’s air crash is supposed to start a core melt sequence. This situation is immediately complicated by the fact that he described a situation where there is a loss of all onsite and offsite electric power. Normally this is the beginning of a station blackout sequence (SBO). However, he derives his source term from NRC publication NUREG-1465 which provides source terms for PWR containments for loss of coolant accidents (LOCAs). The source terms and onsets of releases to the environment for LOCA and SBO events are very different. Further, Lyman does not offer any explanation of how he jumps from an SBO sequence to a LOCA sequence. Additionally, NUREG-1465 provides source terms for two types of loss of coolant accidents, those at high pressure and those at low pressure. The low pressure source term, which corresponds to a large pipe break, is considerably larger than the source term which is tied to a small pipe break. Lyman picked the larger source term associated with a large pipe break, without offering any justification.

As shown below, Lyman’s source term does not agree with the release at Chernobyl, with the NRC, with a recent Indian Point industry study, or with fellow intervenor, Dr.Gordon Thompson. Lyman’s source term is larger than all of the above, but large source terms are necessary to produce large consequences.

5.2 Lyman’s Source Term versus Chernobyl’s Source Term

In spite of the fact that Chernobyl experienced a violent fast breaking accident and the Indian Point design precludes this, Lyman actually proposes a source term for Indian Point that is larger than Chernobyl’s. Without going any further, this comparison demonstrates that the Lyman source term is inaccurate. The reason why Lyman’s source term is too large is provided in Section 5.6.

A comparison of Lyman’s Indian Point source term to Chernobyl’s is presented in TABLE 5-A where core fractions of iodine, cesium, and tellurium released to the environment is presented. It is also important to note that even with the fast breaking accident at Chernobyl, significant core fractions (reference [22]) were **not** released to the environment. This implies that all reactor designs will retain some fraction of their initial inventories of radioactive material even if a fast breaking accident occurred. Designs like Indian Point’s, which can not have fast breaking accidents, would trap an even greater percentage of their initial radioactive inventory than a Chernobyl design, if an accident occurred.

In addition to comparing the Chernobyl and Indian Point <u>core fractions</u> released to the environment, a comparison of the number of megacuries of 137Cs released to the environment has been made. Radioactive cesium is the most important isotope in determining economic losses, land contamination, and long term health effects. According to the Alvarez/Lyman report (reference [23]) about 2 megacuries of 137Cs was released at Chernobyl. (Gordon Thompson gives a value of 2.4 megacuries). The Alvarez/Lyman report states that a 1000 MWe nuclear plant contains about 5 megacuries of 137Cs. Others have estimated Indian Point's cesium inventory at 5.2 megacuries. Using Lyman's core fraction of 0.67 for the cesium release, about 3.35 to 3.48 megacuries would be released from Indian Point. This is about 74% larger than Chernobyl's two megacurie release. Clearly impossible.

5.3 Lyman's Source Term Analysis versus NRC's Source Term Analysis

Lyman is critical of Entergy's use of the MAAP code when determining the cost effectiveness of various SAMAs. Lyman prefers the source term analyses of the NRC which uses the Source Term Code Package (STCP) (reference [24]). Lyman refers to NUREG-1150 Volume 1 (reference [25]) analysis of the Zion plant "a four loop PWR quite similar to the Indian Point reactors" as an example of the use of the STCP.

Lyman's comparison of MAAP to the NRC's STCP is a "red herring". Regardless of any purported differences between NRC's STCP and MAAP, such differences do not support Lyman's source term. To illustrate this, the source term core release fractions for an early release at Zion is provided in TABLE 5-A below and again in graphical form in FIGURE A-3. Even at the 95% confidence level, the Zion early failure core fractions in NUREG-1150 are well bellow Lyman's. Regardless of Lyman's claimed differences between MAAP and the STCP, neither of these codes support Lyman's source term.

5.4 Lyman's Source Term versus RBR's Source Term

A recent analysis of emergency planning at the Indian Point site was conducted by RBR Consultants, Inc. (reference [26]). This RBR report used source terms based on two postulated terrorist events. One sequence modeled a loss of coolant event and the other modeled a station blackout event. In both of these terrorist cases the containment was assumed to be breached immediately with a core melt sequence initiated 30 minutes later. Core fractions for these events are presented in the TABLE 5-A below.

The RBR study also examined postulated accidents at Indian Point, using data from Indian Point 3's Probabilistic Safety Assessment (reference [27]). TABLE 5-A includes frequency weighted core fractions of iodine, tellurium, and cesium based on these accident studies. It is noted that the frequency weighted source terms from hypothetical accidents at Indian Point are about one tenth the size of those used in the assumed terrorist scenarios.

In all cases Lyman's source term is larger than both actual accidents (Chernobyl and Three Mile Island) and other NRC and nuclear industry analytical results based on hypothetical scenarios.

TABLE 5-A Comparison of Source Term Core Fractions

	Iodine	Tellu-rium	Cesium
Lyman's "Chernobyl on the Hudson?" (Indian Point?)	0.67	0.30	0.67
Chernobyl Accident	0.60	0.10	0.40
Three Mile Island Accident,	~0.0	~0.0	~0.0
Zion, NUREG-1150, Early Failure, Mean Value	0.07	0.025	0.040
Zion, NUREG-1150, Early Failure, 95% Value	0.20	0.16	0.18
RBR- LOC Sequence, Containment Breach at T= 0	0.111	0.121	0.101
RBR- SBO Sequence, Containment Breach at T= 0	0.274	0.182	0.186
Indian Point 3, Frequency Weighted Accident Releases, Probabilistic Safety Assessment Results	0.022	0.015	0.015

5.5 Lyman versus Dr. Gordon Thompson

Lyman's terrorist scenario is based on the containment source term for large break LOCAs as described in NUREG-1465. Lyman then postulates that the radioactive material remains within the containment for 1.8 hours and then a pressure spike occurs in the containment due to the failure of the bottom of the reactor vessel. The area in the containment, assumed to be weakened by the airplane crash, then blows open and plume number one is rapidly released to the environment over a period of 0.06 hours. This is followed by plume number two which releases additional radioactive material into the environment over a period of two hours. Fellow intervener Dr.Gordon Thompson (reference [28]) offers a different perspective on source terms "The IP2 and IP3 reactors have large, dry containments. Containments of this type have some capacity to withstand the destructive phenomena that accompany core damage accidents, such as hydrogen explosions or steam explosions. Thus, if containment bypass does not occur, the fraction of radioactive material released from the damaged fuel that reaches the environment might be comparatively small." Thompson's "comparatively small" source term statement for non- bypass events is directly opposite to the very large source term used by Lyman in his COH report. Thompson's statement is consistent with the Zion source term for early releases, as shown in FIGURE A-3.

5.6 Why is Lyman's Source Term so Large?

Lyman's source term is derived from NUREG-1465 "Accident Source Terms for Light-water Nuclear Power Plants". The main purpose of this NUREG is to provide source terms that <u>enter the containment</u> during loss of coolant accidents. However, the amount of radioactive material that enters the containment <u>is different from the amount of radioactive material that enters the environment.</u> NUREG -1465 recognizes that there are numerous removal processes that reduce the inventory of the radioactive material in the containment. These removal processes are discussed extensively in Chapter 5 of NUREG-1465. These removal processes fall into two groups. The first group is engineered safety features such as the containment spray systems. NUREG -1465 provides a formula to determine the removal capability of such sprays. In the case at hand, with the assumption that all sources of electric power have been disabled, the sprays would not work. However, this leaves a group of natural forces that can not be defeated by terrorists and do not require any electric power. NUREG 1465 identifies these removal processes as (1) the effect of water that overlies core debris (2) gravitational settling (3) diffusiophoresis (4) thermophoresis (5) particle diffusion and (6) aerosol agglomeration. It is these removal processes that led to the very small source terms in NUREG-1150's description of the Zion early release scenario, presented in TABLE 5-A and FIGURE A-3.

Lyman dismisses these removal processes "We further assume that the entire radionuclide inventory released from the damaged fuel into the containment escapes into the environment through the rupture in the containment". **This unrealistic assumption has the effect of totally removing the containment, something even more extreme than the Chernobyl plant with its confinement system.**

A more realistic approach would be to recognize that these removal processes would be sequestering radioactive material continuously. Prior to the assumed time that containment integrity is lost in Lyman's analysis, at 1.8 hours, the amount of radioactive material <u>in the containment atmosphere</u> is the amount released into the containment, as given in NUREG-1465, minus the amount sequestered by the removal processes identified in this NUREG. Even if the rapid depressurization envisaged by Lyman swept all of the suspended radioactive material in the containment atmosphere in just 0.06 hours (216 seconds) out into the environment, this would still leave much of the already sequestered radioactive material dissolved in various water pools, stuck to cooler surfaces, under the water that overlies core debris, etc. Once this rapid depressurization process was over, some 216 seconds later, the differential pressure between the inside of the open containment and the outside environment would be far less and closer to a few psid. From that time forward the amount of radioactive material that might enter the environment would be the mass balance between the radioactive material entering the containment, as predicated by NUREG-1465, less the radioactive material that would continue to be sequestered by the various removal processes. In other words, once containment integrity is lost, the removal processes described in NUREG-1465 is supplemented by another removal process, the transport of radioactive material into the environment, driven by the now greatly diminished pressure differential. Because the sequestering removal processes compete with the transport removal process, not all of the radionuclides that enter the containment find their way out to the environment, even after containment integrity is lost.

Lyman ignores these sequestering removal processes both before and after the containment is depressurized. The earlier rapid depressurization that Lyman relies on to sweep out the containment atmosphere is no longer available to Lyman's second plume. Therefore he can not claim that there is a mechanism to rapidly sweep out the radioactive material that might be still evolving from the reactor vessel or from core debris. It is noted that a very large fraction of the source term in NUREG -1465 enters the containment after Lyman's assumed depressurization process is over. For example, 40% of the iodine, 55% of the cesium and 83% of the tellurium enters the containment after Lyman's assumed rapid depressurization. Therefore the importance that Lyman assigns to this rapid depressurization for justifying his very large source term is not valid. Lyman's environmental source term is reproduced below.

TABLE 5-B Lyman's Environmental Source Term

Plume	Release time, (hrs)	Duration (hrs)	Energy release (MW)	Kr	I	Cs	Te	Ba	Ru	Ce	La
1	1.80	0.06	2.8	1.0	0.4	0.3	0.05	0.02	0.0025	0.0005	0.0002
2	1.86	2.00	1.6	0	0.27	0.37	0.25	0.1	0.0025	0.005	0.005

In TABLE 5-A an analysis was made for conditions more severe than Lyman's. In the RBR's Loss of Coolant (LOC) scenario, the case that most closely resembles Lyman's loss of coolant scenario, it was assumed that the containment was breached immediately with a very large opening. While this scenario would eliminate Lyman's rapid depressurization scheme, it did open up the containment to the environment almost two hours earlier. Even with this assumed immediate loss of containment integrity, the natural removal processes, like those identified in NUREG-1465, were sufficient to limit the environmental source term to values well below Lyman's.

Simply stated, Lyman's source term is unrealistically large. Ignoring the effects of natural radionuclide removal processes inside the containment and the absence of a large pressure differential to drive the radioactive material suspended in the containment atmosphere out into the environment are major defects in Lyman's "Chernobyl on the Hudson".

5.7 Effects of Overstating the Source Term

There are numerous effects of an overstated source term. Among these are exaggerated early and long term health effects, overly long ranges over which these early health effects might occur, incorrect determination of the size of the area that might become contaminated, inflated offsite economic losses, and incorrect estimates of the dollar value of cost effective SAMAs. Such exaggerated consequences frighten people and this leads to misplaced political action.

6.0 Heated Plumes

According to Alvarez/Lyman, page 14, about 0.33 trillion joules of heat, or about 92 MW-hours, could be contained in the jet fuel in the type of aircraft that struck the World Trade Center. Based on crash tests conducted by Sandia National Laboratory (Alvarez/Lyman, page 13) a fireball would result from aircrashes above speeds of 135 m.p.h. It was observed that significant fires were initiated by the aircrashes at the World Trade Center and at the Pentagon. The connection between aircraft crashes and subsequent fires is affirmed in NY State's Contention 27, page 237 "The impact of fuel-laden planes caused explosions and large, long-lasting fires. Those explosions and fires destroyed a portion of the Pentagon in northern Virginia and caused the collapse of the World Trade Center towers and nearby buildings in New York City. See Nat'l Comm'n on Terrorist Attacks upon the U.S. ("9/11 Commission"), The 9/11 Commission Report (2004)". Anyone who watched the tragic pictures of the burning World Trade Center buildings would recall the significant buoyant plume coming from these buildings.

Lyman acknowledges the importance of the jet fuel (reference [29]) in the context of his speculations about vibrations causing failure of the emergency diesel generators. "...since the aircraft impact itself, followed by a fuel-air explosion,...". He then adds, two pages later, "Another plume characteristic that is very important to determining the distribution and magnitude of consequences is the heat energy that it contains. The oxidation of zirconium cladding during core degradation generates a large amount of heat in a short period of time, which can cause the plume to become buoyant and rise. Greater initial plume heights result in lower radiological concentrations close to the plant, but wider dispersal of the plume". So within two pages of the COH text he first acknowledges that the aircraft fuel could cause a fuel-air explosion and buoyant plumes would be a very important determinant of the consequences. Indeed, plume buoyant is very important. As stated in the first paragraph of Section 2, for essentially equal releases of radioactive cesium, Lyman gets a factor of about 345 times greater consequences, at peak, when he assumes that the plume is not buoyant.

Beyond Lyman's speculation of the chemical energy in the jet fuel explosion might affect the emergency diesels, he does not explore the full meaning of this additional source of energy and how it would affect plume heating. This critical issue is ignored in spite of the 9/11 Commission's finding that fuel-laden planes created explosions and large, long lasting fires. Whereas Chernobyl had chemical energy added to its plume from the burning of its graphite, an attack by large fuel-laden aircraft would add chemical energy from its jet fuel. Both would have buoyant plumes.

In Lyman's two plume model there is somewhat less than four hours from the initial crash of the airplane to the end of the plume 2 release. Assuming that half of the original 92 MW-hrs of jet fuel energy is consumed by an initial fire ball, this still leaves about 46 MW-hours of heat that would spread out over a period of four hours, or a heat rate of about 11.5 MW. This chemical energy would be added to the internal energy of plumes one and two. The Alvarez/Lyman report (reference [12]) describes, at page 7 and in FIGURE 4, a lofted plume with a heat rate of just 5 MW.

Adding the energy from the fire to the internal energy of plumes would result in energy rates far in excess of 5 MW. When the effects of jet fuel fires are accounted for, the much lower consequences in Lyman's addendum (reference [17]), which addresses heated plumes, should be used instead of the consequences in Lyman's COH. Lyman's addendum consequences, further corrected for a much smaller source term leads to the much lower health and economic consequences[3] as listed in Section 2, above.

Ignoring the effects of jet fuel on plume buoyancy is a major defect in Lyman's "Chernobyl on the Hudson". Additionally, the initial jet fuel blast would further reduce the possibility of obtaining the desired precisely weakened containment that Lyman depends on to develop his rapid depressurization scenario.

Once the Lyman analysis is corrected for smaller source terms and the expected buoyancy due to the jet fuel fire, Lyman's argument about increased thyroid cancers is shown to be invalid.

3 See the appendix for an analysis of consequences from heated plumes.

7.0 The Trip From Indian Point to Mid-Manhattan.

As stated in the Executive Summary, Lyman's COH is not suitable for important decision making because it does not consider probabilities. Lyman's excuse (reference [30]) for not using probabilities is that "Accident probabilities are not relevant for scenarios that are intentionally caused by sabotage". This line of thinking would result in decisions made on the basis of consequences alone and the temptation of interveners to invent scenarios with maximum consequences, regardless of how unlikely they are.

Various other interveners reject the Lyman approach. For example, In Riverkeeper, Contention EC-2, page 54, refers to NEPA,42 U.S.C. section 4321-4370 f: "...1. Inadequate analysis of probability and scope of severe accidents." Although Riverkeeper was commenting on Entergy in this contention, its reference to NEPA applies to all participants in a legal proceeding, including Lyman.

Intervener Dr. Gordon Thompson takes this issue one step further (reference [31]). "In order to consider potential attacks on the IP2 and IP3 plants in the SAMA analyses, it is necessary to assign a probability to each potential attack scenario. At present, there is no statistical basis to support quantitative estimates of these probabilities. However, reasonable assumptions of probability can be postulated and used in SAMA analyses to (i) compare the risks of conventional accidents with the risk of postulated accidents; and (ii) identify and examine SAMAs that reduce these risks.

Here, IRSS provides some illustrative analyses of potential attacks that yield a large atmospheric release from a reactor and/or a pool fire. The probability of such an attack is postulated here to be 1 per 10,000 reactor-years."

Lyman could follow in Dr. Thompson's footsteps. He could make some postulation of the chances of terrorists succeeding in hijacking a large aircraft; then deciding that out of all the soft targets in this target rich area, Indian Point, a hardened site, would be chosen; that the pilot is successful in crashing the plane into one of the containment buildings; that this causes a loss of onsite electric power and the non-electric means to cool the reactor; that other terrorists have been successful in simultaneously causing a loss of offsite power; that the aircrash just weakens the containment in the manner he describes; that somehow a particular type of loss of coolant core melt sequence occurs, not a station blackout or another type of loss of coolant event with a smaller source term; that there is no sequestering of radioactive material by natural processes as described in NUREG-1465 both before and after containment integrity is lost; that a rapid depressurization containment failure mode ensues; that there is no additional plume heating due to jet fuel fires; that the meteorological conditions that are necessary to transport this source term down to mid-Manhattan prevail; and that people in Manhattan do not take any protective actions like taking shelter, even though the scenario is a rain condition that would normally cause people to take shelter and that they would have over nine hours to receive a warning.

Many of the steps in the above paragraph may be too complex to determine, but a reasonable overall conclusion would be that the combined probability of all these steps occurring is effectively zero. If each of these 12 steps had a 10% chance of occurring, the overall probability of Lyman's scenario succeeding would be one chance in a trillion per year.

Some portions of the above series of steps are quantifiable and they should be quantified. If the quantified portions are by themselves a very small number, then the overall product of all these steps, each of which has a probability of less than 1.0, would be exceedingly small. An example of a potentially quantifiable step would first be the determination of the frequency that the meteorological conditions at Indian Point match those assumed in the analysis, i.e., clear weather, winds blowing towards Manhattan at the selected wind speed of about 5 m.p.h., a particular wind stability class and the possibility of precipitation. Then next step would be the determination of the frequency of rain clouds that somehow absorb all of this radioactive release from Indian Point and transport it to mid-Manhattan without raining before it reached Manhattan. Lyman should provide an explanation of how much radioactive cesium is dispersed from the plume by deposition as it travels these 35 miles from Indian Point to mid-Manhattan. Lyman should then use actual weather data to make a determination of how frequently such clouds rain on Manhattan and only rain on Manhattan. If a somewhat different weather scenario was used in Lyman's consequence analyses, it should be explained in detail and its frequency should be given. The end point of these analyses would be a quantification of just the meteorological portion of his very complex scenario. If this by itself is a very small number or zero, the readers should be appraised of that. Analysis of only that which can be quantified should overcome Lyman's reluctance to use probabilities or frequencies, just because some portions of his overall scenario are unknowable.

As part of this exercise Lyman should resolve issues (reference [32]) raised by another intervener, Dr. Bruce A. Egan, who has raised questions about the ability of the MACCS2 code that Lyman uses to accurately calculate consequences. Specifically, Egan states that "...the ATMOS model cannot account for the effect of the complex terrain in which Indian Point is located, will not accurately estimate the dispersion of radionuclides beyond 32 miles...". Yet Lyman's extreme consequences, such as in mid-Manhattan, are even further away than 32 miles. It is stated in the Alvarez/ Lyman paper on page 7 that "It is assumed unrealistically in these stylized cases that the wind direction would be constant". In COH, page 27, Lyman states various limitations to the MACCS2 code such as "Consequently, the code becomes less reliable when predicting dispersion patterns over long distances and long time periods, given the increasing likelihood of wind shifts". Therefore predicting consequences in mid-Manhattan, some 35 miles from Indian Point, is precisely a situation where MACCS2 is least reliable. Lyman should explain how meaningful decisions can be made considering all of the uncertainty in his analysis. Lyman should explain to his readers that low frequency events, especially events with the peak consequences, have the largest uncertainties and that the uncertainty band around this low frequency event is all in the direction of smaller consequences.

Lyman dwells on plume centerline consequences. He should inform his readers that this centerline of the plume is perhaps about 1.5 degrees wide, less than one half of one percent of a circle's circumference, based on FIGURE4 in the Alvarez/Lyman paper. Wind shifts make it highly unlikely that this very narrow portion of the plume will remain in the same location during the two hour plume passage time period. Very small wind shifts would prevent the extreme numbers that Lyman claims. A figure from the RBR report (reference [14]) is provided in the appendix on wind shift probabilities versus time (FIGURE A-4) based on actual Indian Point meteorological data. This figure shows that for the two hour duration of the release, the probability of the wind shifting by 22.5 degrees is about 72%. The probability of a wind shift of just 1.5 degrees during a two hour period is greater than 72%. Lyman should use wind persistence data from New York City to quantify the probability that his centerline plume would stay stationary for two hours. Lyman should also explain to his readers how very sensitive his early fatality peak numbers are to tiny wind shifts. For example, there is about a 70% probability of causing an early fatality with an exposure of 400 rads and minimum medical support. However, if the exposure were half of this, 200 rads, the probability of becoming an early fatality sharply decreases to 0.3%, a 250 fold decrease. Cutting the peak exposure in half would only require a wind shift of about 1.5 degrees. To put this in perspective a wind shift of 1.5 degrees at mid-Manhattan some 35 miles away would only be a circumferential shift of about one mile out of a total circumference of 220 miles. This small shift would decrease Lyman's peak early fatality numbers from 44,000 to about 352, even assuming that his source term releases were as large as he claims. Lyman's peak consequence numbers are useless in terms of serious decision making. Not only are they incorrect because his source term is too large, the slightest wind shift or any protective action that people would take would cause his peak calculated number to plummet.

Lyman should also clarify whether his calculated latent effects are based on exposure to the radioactive plume during its two hours of passage over Manhattan or ten years of exposure of someone living in a contaminated area (reference [33]), as was the case in the Alvarez/Lyman paper. Clarification of the assumed number of years of exposure would be very helpful because some people have been left with the false impression that a prompt evacuation of Manhattan would be necessary to avoid the extreme latent cancers consequences that Lyman has claimed as possible.

Lyman has written that the terrorists would be able to determine the meteorological conditions that would maximize consequences. Since he has access to the weather records he too should be able to estimate the frequency of such a combination of Indian Point and Manhattan weather conditions. If such a joint weather condition might occur, say, once every fifty or one hundred years it is worth knowing in judging the usefulness of COH. Further, it would be useful for national security people to have this information so that they would know when to go on a heightened alert status. Since the terrorists are supposedly "all knowledgeable" they would also be aware that there would be heightened awareness on those days that are their optimum meteorological conditions. These "all knowledgeable" terrorists would also know that the uncertainties in consequence models are very large, especially at long distances from the point of release. They might decide that trying to arrange to hijack a large aircraft and crash it into Indian Point so that a plume might arrive in mid-Manhattan about nine hours later under optimum meteorological conditions is inconsistent with their modus operandi of attacking soft targets which have a high probability of success. Terrorists, after learning that the most probable outcome is near zero early fatalities and a very small increment in the number of latent fatalities of even if the terrorist attack is successful, may decide that nuclear plants are very poor choices for terrorism.

In any case, it would be a public service if Dr.Lyman presented all of his meteorological assumptions and quantifications, even if this had to be treated as confidential material.

8.0 Failing to Take Protective Actions

Lyman makes the ridiculous assumption (reference [34]) that people in Manhattan would fail to take protective actions (e.g., shelter) during a rain storm, following an air attack on Indian Point. A similar nonsensical assumption led to the extreme consequences in the 1982 analysis performed by Sandia National Laboratories and their subsequent misuse. This earlier misuse of the Sandia effort was condemned by the authors, the NRC, and the then Presidential Science Advisor and is condemned by Witt today. Lyman states "Outside of the 10- mile EPZ the baseline dose calculations assume that individuals will take no protective actions. Although this may not be realistic, we believe that it would be inappropriate to assume otherwise. Since NRC and FEMA do not require that any preparation for an emergency be undertaken outside of the 10-mile EPZ, it would not be conservative to assume that individuals outside of the EPZ would receive prompt notification of the event or would know what to do even if they did receive notification."

By no protective actions Lyman is likely assuming that people remain out-of-doors for up to 24 hours. Common sense tells you that most people would be indoors (sheltered) in his rain scenario. Lyman's scenario is assumed to occur at night (because he claims that the wind flow at night would tend to channel plumes down the Hudson towards Manhattan). At night most people are indoors, even if it is not raining. Further, the shielding characteristics of multi-story buildings and the subways in mid-Manhattan are excellent, making them ideal shelters. A rain scenario in Manhattan would have several other consequence-reducing effects. First, it would reduce the inhalation dose, similar to the removal process for containment sprays discussed in NUREG-1465. Lower inhalation doses are particularly helpful when sheltering is the protective action. Second, since this a city analysis, the rain would be carried off by street drains, taking its radioactive content with it. Third, washing down buildings is a decontamination process. The same rain that brings the radioactive material and deposits this on buildings is the rain that also helps to decontaminate them. Therefore economic losses based on rain scenarios in cities likely overstate economic consequences.

Lyman talks about the need for prompt notification. This too is absurd. A hijacked plane which later crashes into Indian Point would be instant news around the world. Further, Lyman's scenario takes 1.8 hours between the initiation of its core melt sequence. Then, at his assumed wind speed of 5 m.p.h., it would take another 7 hours to reach mid-Manhattan from Indian Point for a total time of almost 9 hours. This is far more time than is necessary to give out a warning to take shelter, which most people would be doing any way.

New York City already has extensive emergency planning for terrorist events. Even if New York City did not already have sheltering as one of its primary protective actions, NRC studies (reference [35]) have shown that this response has been successfully implemented on an *ad hoc* basis. One need only recall the tragic moment of 9/11 with thousands of people evacuating the World Trade Center to know that *ad hoc* responses can be highly effective. These victims of terrorism did not have the nine hour warning time of the Lyman scenario.

Sheltering would be highly effective in these circumstances, as Lyman himself has demonstrated. Lyman, in his TABLE 8, presents his results for a sheltering response out to 25 miles from Indian Point. He calculates zero early fatalities. Mid-Manhattan, 10 miles further away, would also have zero early fatalities with a sheltering response. Independent terrorist scenario analyses have shown that sheltering, as close as four miles from Indian Point, would be sufficient to prevent latent fatalities (reference [14]) during plume passage, even for non buoyant plumes. Therefore none of Lyman's health consequences would occur in Manhattan if people temporarily took shelter. This conclusion is also true for people much closer to Indian Point than Manhattan.

Lyman also uses a cancer risk coefficient (reference [36]) of 10^{-3}/person-rem or 1 cancer fatality per 1000 person-rems. Yet a value of 1 cancer fatality per 2000 person-rems (reference [37]) is used in the Alvarez/Lyman paper, the value generally accepted by the National Council on Radiation Protection and Measurements. This inconsistency of a factor of two means that Lyman has overstated the number of cancer fatalities by a factor of two on just this single parameter. Because the number of cancers is overstated by a factor of two the dollar value of cost effective SAMAs are correspondingly overstated, as are other cost figures.

Lyman's mid-Manhattan maximum consequences are inconsistent with common sense, with other independent analyses, and with his own analyses. His comment that his analysis may not be realistic is an understatement.

9.0 Other Inaccuracies, Inadequacies, Absurdities and Misrepresentations

9.1 Introduction

This section identifies other aspects of Lyman's COH that also bring into question the value of his report.

9.2 Lyman Misuses the KLD Evacuation Analysis

Lyman does not justify his selection of a single particular ERPA (Emergency Response Protection Area) out of many.

Since the range of the early fatality risk is about one mile when source terms are properly calculated, the evacuation speed that Lyman uses, based on the whole ten mile EPZ, is irrelevant. What is important in terms of early fatalities is the time/speed to evacuate the innermost one mile.

Lyman takes his version of the KLD analysis's evacuation speed and plugs it into his MACCS2 code consequence analyses. However his merging of KLD results with MACCS2 code is inaccurate. The MACCS2 code is based on all evacuees leaving at the same moment, traveling radially away from the site, at a constant speed. The KLD analysis is far more sophisticated. People leave their initial locations at different time periods based on a distribution determined by the assumed mobilization time. They do not necessarily travel radially away from the site, especially in the complex road network surrounding Indian Point, but travel down the actual road system. Their travel speeds vary with time and traffic scenario, unlike Lyman's MACCS2 analysis. Finally, KLD uses a large number of starting points for their evacuation analysis, not a single ERPA or just one point within an ERPA.

The MACCS2 code evacuation model that Lyman uses is very crude and results in overestimates of health consequences both near and far from the Indian Point site. Lyman's MACCS2 evacuation model assumes that some portion of the population travels in a radial direction that lines up with the assumed direction of the centerline of a plume. This lining up of people and plume centerlines causes very large overestimates of the early fatality consequences and is a significant limitation of the MACCS2. Local roads do not radiate out from Indian Point, but form a pattern that would significantly limit the time that any evacuee would spend at the plume centerline.

These MACCS2/KLD interface issues have been overcome (reference [14]) resulting in much lower and much more realistic consequences. For example, a typical radial evacuation model calculated 124 early fatalities at Indian Point at the 95% exceedence level. The improved model in reference 14 used evacuations that matched the actual road network. This far more realistic analysis resulted in 2 early fatalities at the 95% exceedence level. Lyman's use of the MACCS2 code has been superseded by improved technology and much smaller early fatality consequences have been calculated.

Lyman also chooses an attack at Indian Point at night because the prevailing winds would be blowing towards New York City. He believes that an attack at night is the time that a terrorist attack is most likely to be successful (reference [34]). However, this is incorrect. KLD has calculated evacuation speeds for both daytime and nighttime evacuations and nighttime evacuations are considerably faster. Much of this increase in evacuation speed is due to fewer vehicles in the EPZ- fewer employees, fewer transients, fewer school buses and most people who work outside the EPZ, but live within it, would already be home. Lyman's optimum wind flow direction and KLD nighttime evacuation speeds work in opposite directions in terms of consequence analyses.

Lyman has used outdated technology that leads to overestimates of consequences.

9.3 Consequences and Frequencies

Lyman presents consequences at different weather percentiles. For example, in his TABLE 5, he presents consequences at the mean, 95th percentile, 99.5th percentile and at the peak (100th percentile). However, the higher the percentile, the lower the associated frequency of the purported consequence. Lyman can determine the frequency of the weather scenario from his data base that corresponds to the 95th percentile and others. In order to provide the reader with a better understanding of these higher consequence numbers, Lyman should list them in terms of their risk contribution by multiplying specific consequences by their associated frequencies. Alternatively, consequence results are often presented in a graph which plots frequency (or probability) versus consequences. Lyman's TABLE 5 should be replaced with this more acceptable presentation format.

Additionally, Lyman does not identify the dose reduction factor he used for ground shine. If this has been omitted from his MACCS2 analysis, it would be a serious error.

Lyman's lack of providing any risk information, which would require the presentation of both consequences and probabilities, is contrary to the recent successful actions by one of New York State's Congressional representatives (reference [38]) who argued that the distribution of the Department of Homeland Security funds should be made on the basis of risk. Further, this distribution could be done efficiently in Westchester County because a classified analysis has been made of the risks of many potential targets in the area[4], including Indian Point. This classified analysis could also be insightful if it ranked Indian Point low on its list.

9.4 Mutually Exclusive Scenarios

On page 39 of COH Lyman states “In the following tables, it is important to note that the peak results in each category do not correspond in general to the same weather sequence. For example, the weather conditions that lead to the maximum number of early fatalities are typically those that involve rainout and substantial deposition of the plume close to the plant, and thus are not the same conditions that lead to peak latent cancer fatalities, which involve rainout of the plume over New York City.”

In spite of acknowledging that these consequence results represent different weather sequences, Lyman’s TABLEs 3,4,5, and 9 present early and latent results which are mutually exclusive and can leave the impression that both extremes can happen from a single event, especially if such tables are quoted out of the context given on page 39. This is more than a matter of a poor or misleading presentation. Later when Lyman calculates the cost of offsite health effects he combines the early fatality costs with the latent fatality costs. It would be acceptable to combine early and latent health effects in a single scenario, but is misleading when the early fatality costs are derived from one scenario and the latent fatality costs are derived from a different scenario.

Lyman complains that Entergy did not correctly calculate offsite costs (reference [39]) because it omitted costs associated with early fatalities. However, a check of Lyman’s own cost calculations show that this factor is only about 2 to 3 percent of the total costs. Once a correct source term is used and plume buoyancy is accounted for this small percentage will become near zero. The importance of Lyman’s complaint is greatly exaggerated.

9.5 NUREG-1465 Source Terms versus CRAC2 Source Terms

On page 16 of COH Lyman claims that the source terms in the state -of-the- art NUREG-1465 report was little different from the source terms in the CRAC2 report (Sandia study). This is wrong. In fact, Robert M. Bernero, NRC director who wrote the forward to the 1982 Sandia report (reference [40]), stated that “Currently there is significant controversy about the realism of accident source terms...”. Years of worldwide research has largely resolved this controversy. Today there are much smaller environmental source terms than what was used in the old CRAC-2 analysis, based on a great deal of experimental data and code development.

The CRAC2 source term describes the amounts and types of radioactive material that was assumed to enter the <u>environment.</u> NUREG-1465 describes the amounts and types of radioactive material that would enter the <u>containment</u> and the various removal processes that would affect this containment source term over time. It is only through Lyman’s misuse of NUREG-1465 does one get a containment source term to resemble an environmental source term like those in a CRAC2 analysis. If the containment and environmental source terms were truly quite similar, that a great deal of source term research money spent around the world would have been wasted.

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4 Announced by Westchester County Executive Andrew Spano at a public meeting.

10.0 Appendix: Correcting Lyman's Consequences

10.1 Introduction

This appendix presents information in three subsections. Section 10.2 corrects Lyman's health and economic consequences by utilizing other information that Lyman has produced and some independent analyses. Section 10.2 also addresses calculated consequences for some terrorist sequences not considered by Lyman.

Section 10.3 reproduces a figure from NUREG-1150's analysis of a source term from Zion, a plant quite similar to Indian Point, for an early release sequence. The Zion plant, also referred to by Lyman, shows much a smaller source term than Lyman used. This figure underscores the observation that Lyman's comparison of MAAP to the STCP is a "red herring" because the STCP analysis does not have a source term nearly as large as what Lyman claims.

Section 10.4 is just a single figure that plots the probability of wind shifts versus time, using Indian Point meteorological data. These data show that there is an extremely small probability that the centerline of a plume will remain stationary for the duration of a release from a damaged plant. On the basis of measured meteorological data, the centerline consequences that he claims is not meaningful because it is so unlikely. This conclusion is further supported by the fact that Lyman's source term is too large. Correcting the source term plus accounting for the very low probability that the centerline of the plume would remain stationary for long periods of time leads to the conclusion that the centerline doses that Lyman has published are not risk significant and perhaps impossible.

10.2 Corrected Health Consequences

10.2.1 Latent fatality consequences

Lyman claims a latent fatality consequences for an air attack on Indian Point in the range of 28,100 to 518,000. Three areas that would greatly reduce these inflated numbers are realistic risk coefficients, proper treatment of plume buoyancy, and more accurate source terms. As already discussed in Section 8, Lyman's COH conversion factor between person-rems of exposure and latent fatalities is inconsistent with the commonly accepted conversion factor, such as that used in the Alverez/Lyman report. Use of the generally accepted conversion factor would decrease Lyman's COH latent fatality figures by a factor of two, i.e. 518,000 latent fatalities would become 259,000 latent fatalities or a quarter of a million fewer latent fatalities at his peak weather conditions.

With regard to plume buoyancy, TABLE A-1 below reproduces TABLE 3 from Beyea, Lyman and von Hippel's addendum (reference [10]) to the Alvarez/Lyman paper. This addendum gives latent fatality estimates for assumed releases of 3.5 and 35 MCi ^{137}Cs. These consequence estimates are for five sites, including Indian Point, from assumed zirconium fires in drained spent fuel pools that lead to the release of ^{137}Cs in a buoyant plume.

The calculated health consequences presented in TABLE A-1 show that Indian Point is somewhat below the average of these five sites and somewhat above average for the offsite economic losses.

Stated differently, these results by Beyea, Lyman, and von Hippel demonstrate that the Indian Point site is quite average when it comes to the risks of long term health effects and offsite economic losses. These conclusions are supported by FIGURE 1 of the same reference, which plots the cumulative population versus distance for these five sites. The cumulative population surrounding Indian Point is somewhat below the average of these five sites when integrated out to distances that capture the bulk of the long term health effects. This integration is taken over a very long distance because, as these authors point out on page 7 of the addendum, "...most of the population dose occurs at larger distances (small doses to large numbers of people)...".

Interveners often talk about the large number of people in the 50 mile radius surrounding Indian Point. However Beyea, Lyman and von Hippel have shown that comparing Indian Point's population at 50 miles to other sites is irrelevant since it is at distances larger than 50 miles where the greatest population dose occurs. At these appropriately larger distances, the Indian Point site is rather average. Fifty mile population comparisons are also irrelevant for early fatalities, which are limited to a range of about one mile (reference [14]). Therefore intervener statements about Indian Point's comparatively larger 50 mile population than other nuclear power sites, while true, are irrelevant.

FIGURE A-1 utilizes the Indian Point data from TABLE A-1 to plot cancer deaths versus the size of the ^{137}Cs release, in megacuries. Based on TABLE A-1, a 35 MCi release of cesium from Indian Point would result in 5600 cancer deaths and a release of 3.5 MCi would result in 1500 cancer deaths. It was possible to add a third point: the number of cancer deaths would be zero if the number of released megacuries of ^{137}Cs were also zero. This third point is similar to the Three Mile Island accident which, effectively, had a zero cesium release.

Having now developed a correlation between megacuries of released cesium and the estimated number of cancer deaths for buoyant plumes at Indian Point based on TABLE A-1, it is possible to make two comparisons to this correlation: the WHO Chernobyl cancer estimate of the number of cancer deaths and those claimed by Lyman in COH. Chernobyl had a buoyant plume because of its power excursion and graphite fire, plumes from fires in drained spent fuel pools would be buoyant, and plumes from airplane attacks on Indian Point would be buoyant because of explosions and long lasting fires from the ignition of jet fuel. Therefore it is appropriate to compare consequences from Chernobyl, drained spent fuel pools and COH as a function of the amount of radioactive cesium that is released because all three circumstances would have buoyant plumes.

Chernobyl released about 2 MCi of ^{137}Cs and about 3000 cancer deaths are estimated (See Section 1.0) as the result of this accident. This correlates reasonably well with the addendum results, especially considering the uncertainties in all of these analyses. In Lyman's COH the cesium core fraction that was released to the environment was 0.67. According to Alvarez/Lyman, the Indian Point core cesium inventory is about 5 MCi, therefore the COH cesium release would be about (0.67)(5) = 3.35 MCi. The COH release is quite similar to the 3.50 MCi assumed to be released from Indian Point's spent fuel pool in the Alvarez/Lyman report. Therefore when plume buoyancy is accounted for a release of 3.35 MCi should be somewhat smaller than the 3.5 MCi value on the correlation line, i.e., somewhat less than 1500 cancer deaths. TABLE 3 from COH (reference [13]) was used to give the range of cancer deaths from 28,100 for the mean value to 518,000 for the peak value. However, unlike the Chernobyl results that correlate well with FIGURE A-1, the COH calculated cancer deaths are literally off the charts.

The third correction for Lyman's cancer deaths number is due to the use of more realistic source terms. The RBR loss of coolant (LOC) terrorist sequence, which is most like Lyman's loss of coolant terrorist sequence, has a calculated core release fraction of 0.101. This equates to a release of (0.101)(5) =0.505 MCi of ^{137}Cs. A buoyant release of this magnitude might result in about 200 cancer deaths.

Using Lyman's mean number of cancer deaths of 28,100, the correction for the person-rem/latent cancer deaths would reduce this large value to about 14,050. The second correction for plume buoyancy would decrease the 14,050 number down to around 1450 and the source term correction would reduce the 1450 number down to around 200. All told Lyman's mean number of latent fatality deaths appears to be too large by a factor of about 28,100/200 = 140.

As discussed in Section 5.1, Lyman assumes a scenario that first appears to be a station blackout scenario, but then, inexplicably, transforms this into a loss of coolant scenario. Using the results from the RBR analysis, an estimation was made of the cancer deaths from a station blackout scenario, using FIGURE A-1. The RBR SBO terrorist sequence with its 0.186 cesium release fraction equates to a release of 0.930 MCi of ^{137}Cs. The larger release from a SBO sequence would result in about 400 cancer deaths, based on FIGURE A-1. Therefore, over a wide range of scenarios and source terms the expected number of latent fatalities is in the range of 200 to 400, assuming that such an improbable attack could even succeed.

A summary of the number of estimated cancer deaths in these various analyses is presented below in TABLE A-2.

TABLE A-1 Lyman's Buoyant Plumes

Consequence Estimates of Economic Losses (Billions) and Cancer Deaths

Site	**Release MCi**	Total Costs	Con-demned Property	Other Losses	Tempo-rary Location	Decon-tamination	Cancer Deaths
Catawba	**3.5**	76	10	32	0	29	3100
Catawba	**35**	547	145	192	11	199	7650
Indian Point	**3.5**	145	43	42	5	56	1500
Indian Point	**35**	461	282	85	8	86	5600
LaSalle	**3.5**	54	10	23	1	27	2100
LaSalle	**35**	80	20	121	7	131	6400
Palo Verde	**3.5**	11	2	5	0	5	600
Palo Verde	**35**	80	24	26	2	29	2000
3 Mile Island	**3.5**	171	13	65	6	87	2300
3 Mile Island	**35**	568	278	134	11	144	7000
Average	**3.5**	91					**1900**
Average	**35**	347					**5700**

TABLE A-2 Estimated Latent Cancer Deaths

Situation	Latent Cancer Deaths
Lyman's "Chernobyl on the Hudson?"	28,100 to 518,000
Chernobyl Accident	~3000
Three Mile Island Accident,	~0
COH with correct conversion factor, mean value	~14,050
COH with correct conversion factor and with buoyancy, mean value	~1450
COH with above corrections, but using the RBR LOC source term, mean value	~200
COH with above corrections, but using the RBR SBO source term, mean value	~400

10.2.2 Early fatality consequences

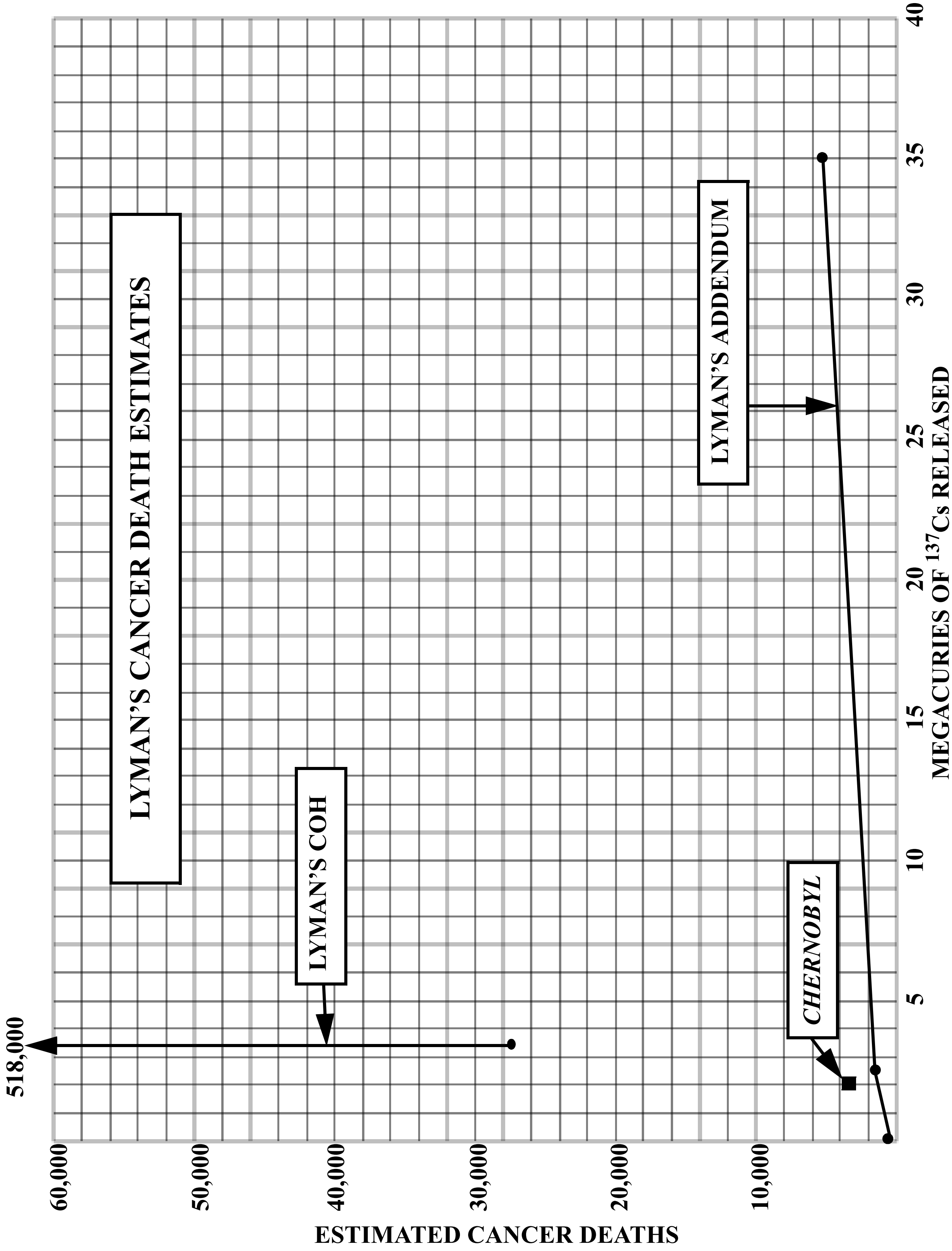
TABLE A-3 compares the number of early fatalities from COH, the Chernobyl Accident, Three Mile Island, from fires in spent fuel pools, and from the RBR LOC and RBR SBO analyses. The Chernobyl accident did not have any early fatalities among the general public because the plume buoyancy made ground level radiation exposures too small to cause an early fatality. It is expected that this would also be the case for an airplane crash into Indian Point because of the plume buoyancy due to the burning of the jet fuel. The Three Mile Island accident did not have any early fatalities because of the release of radioactive material to the public was very small. Fires in spent fuel pools are unlikely to cause any early fatalities because the plumes would be buoyant and because the amounts of radioactive iodine and tellurium decay to very low levels in comparatively short time periods. Radioactive iodine and tellurium are the most important contributors to early health effects.

It is possible to compare the above results to other calculated terrorist events that did not include a buoyant plume. In TABLE A-3 the RBR results are taken from reference 14 which had much more realistic source terms as well as sophisticated KLD evacuation analyses. Technologies were developed that permitted the merging of the MACCS2 code with these sophisticated KLD results. If the plume were buoyant, then the Chernobyl experience would be repeated, with zero early fatalities for both the COH and RBR analyses. As it is, the RBR results are at or near zero even without plume heating. Therefore they are useful in judging other terrorist events that do not have the jet fuel of an airplane crash or other causes of a buoyant plume.

TABLE A-3 Estimated Early Fatalities

Situation	Early fatalities
Lyman’s “Chernobyl on the Hudson?”, mean value and 95% value, non buoyant plume	527 to 2440
Chernobyl Accident, buoyant plume	~0
Three Mile Island Accident, ~ no release	~0
Fires in a spent fuel pool, buoyant plume, ~no iodine or tellurium	~0
RBR LOC source term, mean value, 95% value, non buoyant plume	~0, ~5
RBR SBO source term, mean value, 95% value, non buoyant plume	~0,~0

FIGURE A-1 Lyman's Cancer Death Estimates



10.2.3 Economic consequences

The cost data from TABLE A-1 for Indian Point was used to generate total costs versus cesium release. At an assumed release of 35 MCi, TABLE A-1 lists offsite economic losses at 461 billion dollars. At an assumed release of 3.5 MCi TABLE A-1 lists economic losses at 145 billion. As in the case of FIGURE A-1 a third point was generated where a zero release of radioactive material would result in a zero offsite cost due to actual radiation issues. These three points are plotted in FIGURE A-2.

Once again, the COH's TABLE 9 cost figure from 371 billion dollars to 2.1 trillion dollars is totally inconsistent with Lyman's own TABLE A-1. If COH's unrealistic source term were replaced by the more accurate RBR LOC source term and if the plume were buoyant, then around 20 billion dollars in losses might occur for a successful terrorist event with a large aircraft. If the larger RBR SBO is used and a buoyant plume is assumed, then economic loses might be in the neighborhood of 40 billion dollars. More realistic estimates of offsite losses, which take into account wind shifts, should result in lower cost estimates for all of these scenarios.

The offsite economic losses for other types of terrorist events that do not involve plume heating were not calculated. Accidents are not expected to be buoyant and would have to be separately calculated. However, accidents would have much smaller cesium releases on average and should result in offsite cost figures below $20 billion. All of these results are compared in the TABLE A-4, below.

TABLE A-4 Comparison of Offsite Economic Losses due to Radiation

Situation	Offsite Economic Losses, Billions
Lyman's "Chernobyl on the Hudson?", non buoyant plume	371 to 2100
Three Mile Island Accident, ~ no offsite release	~0
Fires in an Indian Point spent fuel pool, buoyant plume, (TABLE A-1)	145 to 461
COH using RBR LOC source term, buoyant plume	~20
COH using RBR SBO source term, buoyant plume	~40
Accidents at Indian Point, non buoyant plumes	Not investigated here, but average source terms are much smaller than RBR source terms. Economic losses would likely to be below 20 billion dollars.

FIGURE A-2 Lyman's Indian Point Offsite Cost Estimates, Billions of Dollars

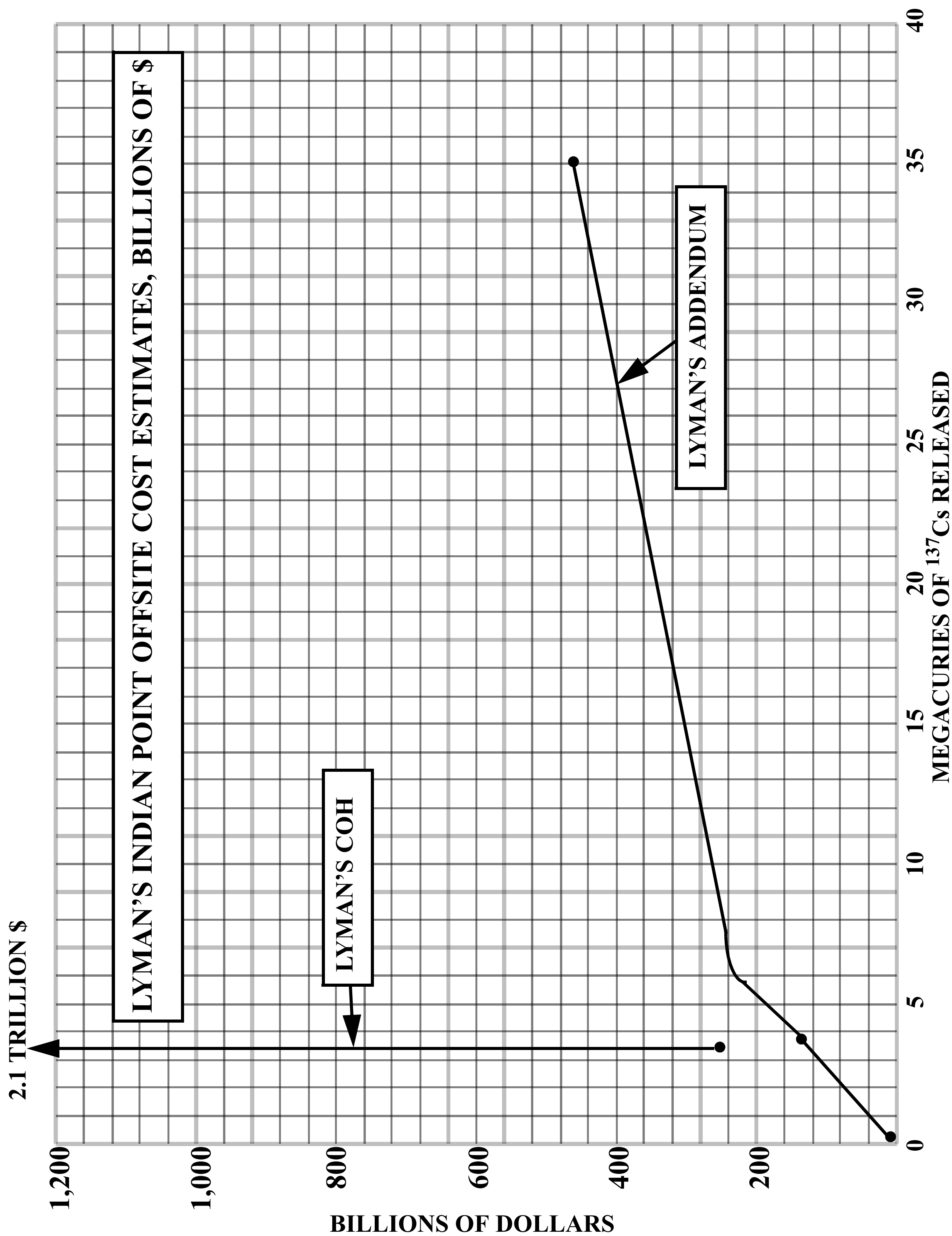


FIGURE A-3 Zion Source Term

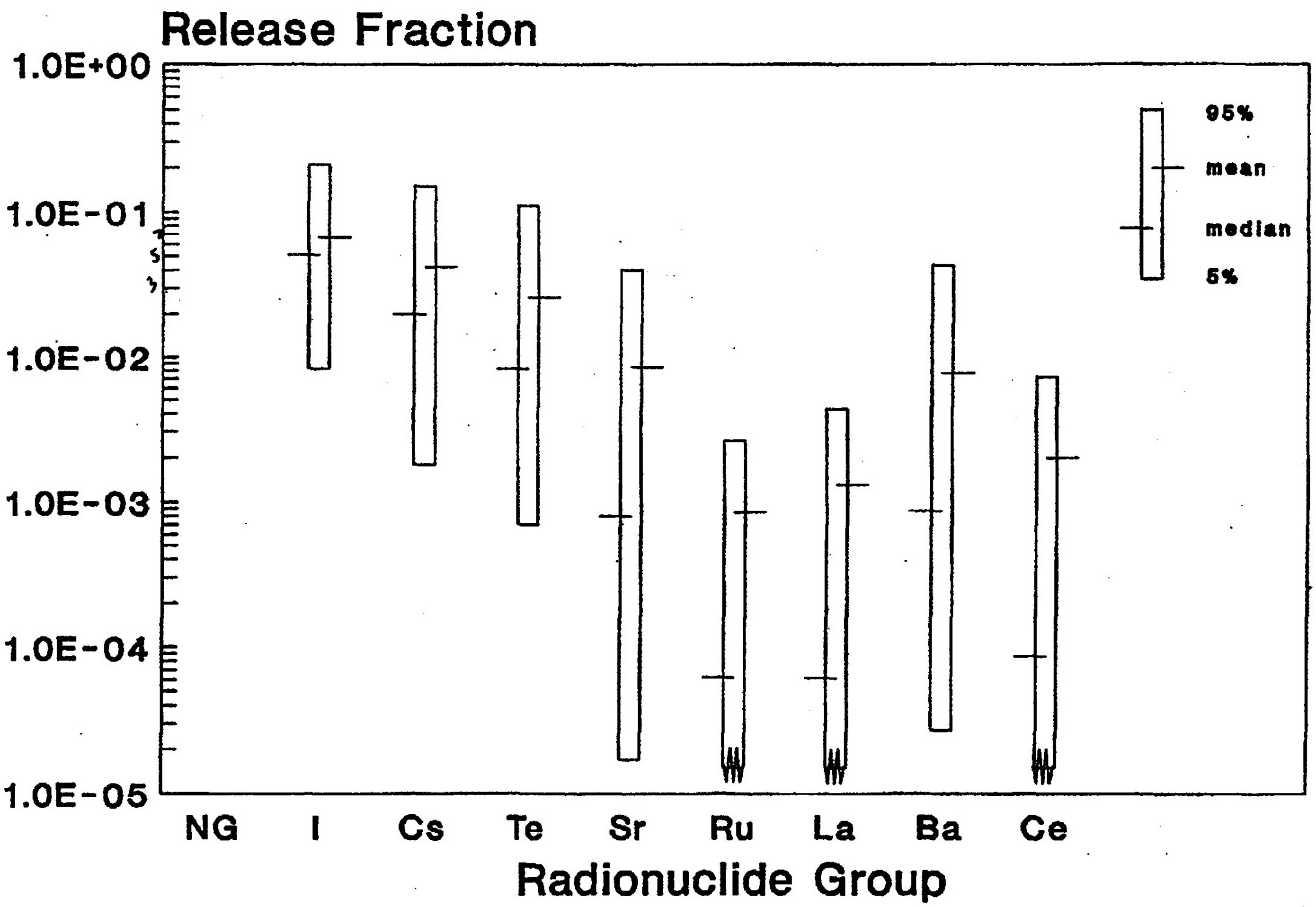
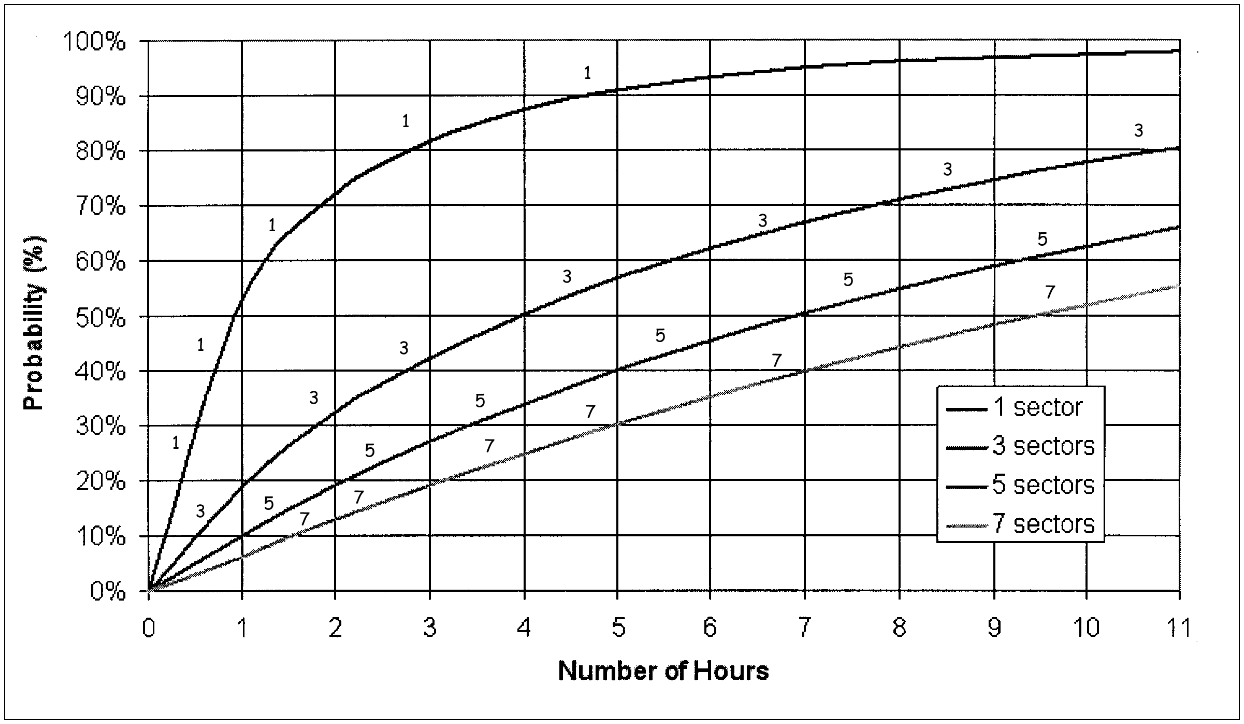


Figure 7.5 Source term distributions for early containment failure at Zion.

FIGURE A-4 Probability of Wind Shifts at Indian Point versus Hours



11.0 References

1. *Is Atomic Radiation as Dangerous as we Thought?* Der Spiegel, SPIEGEL ONLINE, November 22, 2007.
2. *A Review of Emergency Preparedness at Indian Point and Millstone,* Draft, James Lee Witt Associates, LLC, January 10, 2003, Section 7.1.
3. *Health Effects of the Chernobyl Accident and Special Health Care Programmes*, World Health Organization, Geneva, 2006,Chapter 1, page 2.
4. *WHO l Chernobyl: The True Scale of the Accident,* http://www.who.int/mediacentre/news/releases/2005/pr38/en/index1.html.
5. Dr. Robert Alvarez, et al, *Reducing the Hazards From Stored Spent Power-Reactor Fuel in the United States*, Science and Global Security 11, 2003.
6. "*Safety and Security of Commercial Spent Nuclear Fuel Storage,* National Academies Press, 2006, page 50.
7. *Op cit.*, page 9.
8. Dr. Gordon R. Thompson, *Risk-Related Impacts from Continued Operation of Indian Point Nuclear Power Plants*, November, 2007, Riverkeeper Contention EC-2, page 19.
9. Herschel Specter, *Analysis of Attacks on Spent Fuel Pools,* PSA'05, San Francisco, California, April, 2005.
10. Dr. Jan Beyea, Dr. Edwin Lyman and Professor Frank von Hippel, *Damages from a Major Release of ^{137}Cs into the Atmosphere of the United States,* Science and Global Security, (2004) 1-12.
11. Matthew L. Wald, *U.S. Science Panel Sees Big Problems if Indian Point Reactors are Closed,* New York Times, June 7, 2006.
12. Dr. Robert Alvarez, et al, *Reducing the Hazards From Stored Spent Power-Reactor Fuel in the United States*, Science and Global Security 11, 2003, page 14 and footnote 41.
13. NUREG -1465, *Accident Source Terms for Light-Water Power Plants*, L. Soffer et al, U.S. Nuclear Regulatory Commission, February, 1995.
14. *Enhanced Emergency Planning,* RBR Consultants, Inc., December, 2007, TABLE A-5.
15. Dr. E. Lyman, *"Chernobyl on the Hudson?"*, September, 2004, Executive Summary, page 5.
16. *Enhanced Emergency Planning,* RBR Consultants, Inc., December, 2007, Executive Summary.
17. Dr. Jan Beyea, Dr. Edwin Lyman and Professor Frank von Hippel, *Damages from a Major Release of ^{137}Cs into the Atmosphere of the United States,* Science and Global Security, (2004) 1-12, TABLE 3.
18. *Enhanced Emergency Planning,* RBR Consultants, Inc., December, 2007, Exhibit A-2.
19. Dr. E. Lyman, *"Chernobyl on the Hudson?"*, September, 2004, TABLE 2.
20. Ann Taylor, *New Alarms Heat Up Debate on Publicizing Chemical Risks*, Wall Street Journal, May 30, 2002.

21. Dr. Gordon R. Thompson, *Risk-Related Impacts from Continued Operation of Indian Point Nuclear Power Plants*, November, 2007, Riverkeeper Contention EC-2, page 44
22. P.H.Gudiksen, T.F. Harvey, and R. Lange, Lawrence Livermore Laboratories, *Chernobyl Source Term,* Energy Citations Database OSTI: 5087075, November 1, 1989.
23. Dr. Robert Alvarez, et al, *Reducing the Hazards From Stored Spent Power-Reactor Fuel in the United States*, Science and Global Security 11, 2003, page 7.
24. Dr. E. Lyman, *"A Critique of the Radiological Consequence Assessment Conducted in Support of the Indian Point Severe Accident Mitigation Alternatives Program"*, page 3.
25. *Severe Accident Risks: An Assessment of Five U.S. Nuclear Power Plants,* NUREG-1150, 1991.
26. *Enhanced Emergency Planning,* RBR Consultants, Inc., December, 2007.
27. *Indian Point Unit 3 Nuclear Power Plant Probabilistic Safety Assessment,* Revision 2, IP-RPT-06-00071, March, 2007.
28. Dr. Gordon R. Thompson, *Risk-Related Impacts from Continued Operation of Indian Point Nuclear Power Plants*, November, 2007, Riverkeeper Contention EC-2, page 14.
29. Dr. E. Lyman, *"Chernobyl on the Hudson?"*, September, 2004, page 30.
30. *Op cit.*, page 16.
31. Dr. Gordon R. Thompson, *Risk-Related Impacts from Continued Operation of Indian Point Nuclear Power Plants*, November, 2007, Riverkeeper Contention EC-2, page 45.
32. Dr. Bruce A Egan, NY State's contentions, Volume II, page 1.
33. Dr. Robert Alvarez, et al, *Reducing the Hazards From Stored Spent Power-Reactor Fuel in the United States*, Science and Global Security 11, 2003, page 10.
34. Dr. E. Lyman, *"Chernobyl on the Hudson?"*, September, 2004, page 36.
35. *Review of NUREG-0654, Supplement 3, "Criteria for Protective Action Recommendations for Severe Accidents"*, USNRC, SECY-07-0225, December 29, 2007, page 59.
36. Dr. E. Lyman, *"A Critique of the Radiological Consequence Assessment Conducted in Support of the Indian Point Severe Accident Mitigation Alternatives Program"*, page 6.
37. Dr. Robert Alvarez, et al, *Reducing the Hazards From Stored Spent Power-Reactor Fuel in the United States*, Science and Global Security 11, 2003, footnote 32.
38. *Working for the 18th District*, Newsletter of Congresswoman Nita Lowey, January 2008
39. Dr. E. Lyman, *"A Critique of the Radiological Consequence Assessment Conducted in Support of the Indian Point Severe Accident Mitigation Alternatives Program"*, page 5.
40. *Technical Guidance for Siting Criteria Development,* NUREG/CR-2239, SAND81-1549, 1982.