POLICY ISSUE
NOTATION VOTE

March 4, 2008 SECY-08-0029

FOR: The Commissioners

FROM: Luis A. Reyes
Executive Director for Operations

SUBJECT: STATE-OF-THE-ART REACTOR CONSEQUENCE ANALYSES — REPORTING OFFSITE HEALTH CONSEQUENCES

PURPOSE:

The purpose of this paper is to obtain Commission approval of the staff-recommended methodology for projecting latent cancer health effects (latent cancer fatalities (LCFs)) in the state-of-the-art reactor consequences analyses (SOARCA). The staff is also seeking approval to proceed with an external peer review of the methods and technical issues associated with assessing offsite health consequences. This paper does not address any new commitments or resource implications.

SUMMARY:

The staff provided its proposed plan to perform an updated realistic evaluation of potential severe reactor accidents and their offsite consequences in SECY-05-0233, "Plan for Developing State-of-the-Art Reactor Consequence Analyses," dated December 22, 2005. In its effort to provide more realistic information to the public and other stakeholders, including Federal, State, and local authorities, on potential nuclear power plant consequences, the staff is using the best available data on plant design and operation; state-of-the-art information on accident progression, source term, and containment performance; and the best practices in emergency preparedness. For the Peach Bottom and Surry accident scenarios studied in the SOARCA, the

CONTACT: Jocelyn Mitchell, RES/DSA
301-415-5289

staff identified those dominant events as scenarios that have a core damage frequency of 10^{-6} or greater per reactor year or containment bypass scenarios that have a frequency of 10^{-7} or greater per reactor year. These core damage frequencies were based on existing Standardized Probabilistic Analysis Risk (SPAR) models. The accident progression analyses for these sites considered additional mitigation measures that were not credited in previous models and analyses. The staff also performed sensitivity studies to understand the value of those mitigation measures.

In considering how to communicate any results that may be obtained, the staff has concluded that the modeling methodology for projecting LCFs from offsite radiological releases described in SECY-05-0233 may not be the best approach to achieve the Commission's objectives for SOARCA. This is because the prediction of the LCFs is problematic, in that computation of potential LCFs for some dose response models aggregates all exposures, including trivial exposures to large populations.

The staff evaluated six different methodologies for projecting LCFs, including the methodology of using multiple dose thresholds for health effects from zero (linear, no threshold (LNT)) to 0.05 sievert (Sv) (5 rem) as described in SECY-05-0233. This evaluation considered the views and opinions of the senior health physicists from across the various U.S. Nuclear Regulatory Commission (NRC) offices, as well as the recommendations of various professional organizations, including the International Commission on Radiological Protection (ICRP), the National Commission on Radiation Protection and Measurements (NCRP), and the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). The goal of this evaluation was to identify a methodology that could be in conformance with the views within the scientific community and could be communicated most effectively to the NRC's internal and external stakeholders.

The staff developed a recommendation, supported by the SOARCA Steering Committee, for Commission consideration. The staff recommends that potential LCFs be expressed as the mean likelihood of LCF for a population-weighted, age and gender averaged, individual living within various distances from the facility. A linear model would be used without a threshold (LNT) and with a truncation at 100 microsieverts (µSv) (10 millirem (mrem)).

<u>BACKGROUND</u>:

In SECY-05-0233, the staff provided its proposed plan to perform an updated realistic evaluation of severe reactor accidents and their offsite consequences. The plan describes the staff's intention to incorporate the significant improvements in understanding and modeling of severe accident phenomenology that have been developed through research conducted by the NRC and foreign entities over the last 20 years. The plan describes the staff's intent to include in its analysis both the plant improvements (e.g., systems, training, and procedures) that have significantly lowered the likelihood of a severe accident as well as offsite emergency response capabilities that have lowered the offsite health consequences of such events. The study is also designed to effectively communicate the results to all stakeholders based on realistic estimates of the more likely outcomes.

The SOARCA development plan focuses on dominant events in order to provide proper risk perspective. The staff identified those dominant events as scenarios (i.e., groups of similar sequences) that have a core damage frequency equal to or greater than 10^{-6} per reactor year or containment bypass scenarios that have a frequency equal to or greater than 10^{-7} per reactor year. These frequencies were based on guidance from the Commission, general consistency with risk-informed criteria for assessing plant changes, and insights from the initial SOARCA examinations. For the Peach Bottom and Surry accident scenarios studied in the SOARCA, the accident progression analyses considered additional mitigation measures that were not credited in previous models and studies. The staff also performed sensitivity studies to understand the value of these mitigation measures.

When considering ways to perform the offsite consequence analysis more realistically, the staff originally proposed to use a linear dose response model and a range of dose threshold values (i.e., dose truncation values) varying from 0 to 0.05 Sv (5 rem) for estimating offsite LCFs. More recently, in a memorandum to the Commission, "Revised Communication Plan and Project Plan for State-of-the-Art Reactor Consequence Analysis," dated July 9, 2007, the staff stated that it was reviewing several options to develop a more realistic estimate of the health effects risk that the agency could effectively communicate to its stakeholders. Since then, the staff has discussed at length the appropriate truncation values and the means to communicate SOARCA results. These considerable discussions have caused the staff to consider additional alternatives. Issues, alternatives, and the recommended approach are discussed below and in more detail in the enclosure.

DISCUSSION:

As the SOARCA study proceeded during the last year, staff members have had a high level of interest in as well as disparate views regarding the best way to calculate the health consequences of nuclear power plant accidents, particularly as they relate to the dose model and the range of dose thresholds (i.e., dose truncation values), and the best method to communicate the results to stakeholders.

With regard to the dose response model and dose truncation values to use in calculating the health consequences of a severe reactor accident, previous studies have traditionally used a LNT model and have aggregated doses over all individuals projected to receive any exposure. Indeed, several scientific organizations (e.g., ICRP, the U.S. National Academies, and UNSCEAR) have each indicated that the current scientific evidence is consistent with the hypothesis that an LNT dose response relationship exists between exposure to ionizing radiation and the development of cancer in humans. However, some of those same organizations have also stated that aggregation of small or trivial doses should not be used for risk projection. For example, in ICRP Report 103, "The 2007 Recommendations of the International Commission on Radiological Protection," approved March 2007, ICRP stated that risk projection of cancer deaths using the LNT model, which is based on collective effective doses involving trivial exposures to thousands of people, is not reasonable and should be avoided.

The question remains regarding the dose response model and dose truncation values that the SOARCA should use. The staff believes that, as a matter of policy, the NRC could use different approaches for different applications. Regardless of what model is used as the state of the art for projecting population LCFs, the use of a linear dose response model remains an appropriate technical foundation for the agency's regulatory defense-in-depth approach to protect public health and safety. Because the SOARCA is not a regulatory analysis, but rather a more realistic representation of the consequences of severe reactor accidents, the use of a single truncation dose and the exclusion of low radiation exposures to members of the public may be seen as more appropriate and may more realistically describe the offsite health consequences.

With regard to communicating the risk to stakeholders, the staff discussed the advantages and disadvantages of the approach described in SECY-05-0233 for presenting the SOARCA results in terms of multiple offsite health consequences for each accident sequence analyzed, using a range of dose truncation values. The staff was concerned that this approach would not represent effective risk communication in that it might be difficult to provide a context for multiple LCF estimates and might hamper the ability to articulate which of the estimates reflects the staff's best estimate of the more likely outcome. For example, even though the 1982 Sandia siting study (NUREG/CR-2239, "Technical Guidance for Siting Criteria Development," issued December 1982) includes the results of consequence analyses for several scenarios with moderate consequences, advocacy groups rarely mention these results and often quote the most severe (and most unlikely) outcomes of a highly improbable scenario. It can be argued that presenting different values would make it difficult for stakeholders to have a common understanding of the results and could lead to selective misinterpretation.

With this information in mind, the staff assessed several alternatives for calculating the offsite health consequences to determine an appropriate SOARCA dose model that would eliminate the concern about using collective effective doses in risk projection and ensure that the agency can effectively communicate the results to stakeholders. The staff considered several linear models with different truncation criteria. In addition, the staff considered an alternative (alternative (6) described below) that does not report consequences in terms of absolute values of early fatalities and LCFs. In this alternative, the consequences would be expressed as the likelihood of an individual's death given a severe reactor accident. The mean probability of an individual's LCF from an accident would be computed for an average person; that is, the probability would be population weighted and age and gender averaged. (Consequence analyses routinely use this averaging process.) The mean individual risk would be calculated using LNT and a truncation dose of 100 µSv (10 mrem). The calculation would be performed for three distances: (1) 0 to 16.1 kilometers (km) (10 miles) (comparable to the safety goal); (2) 0 to 80.5 km (50 miles) (comparable to cost-benefit analysis); and (3) 0 to 161 km (100 miles). This metric is not new; past Environmental Impact Statements have used it (see, for instance, NUREC-0537, "Final Environmental Impact Statement Related to the Operation of Midland Plant, Units 1 and 2," issued July 1982). Furthermore, this approach is similar to the one the Commission used in establishing its Safety Goals.

Alternatives for Addressing Offsite Latent Health Consequences

Given the above, the potential policy implications, and the high level of stakeholder interest, the staff identified the following six alternatives and a recommendation for Commission consideration.

(1) Assess LCFs using a range of dose truncation values, from 0 to 0.05 Sv (5 rem).

The staff proposed this option to the Commission in SECY-05-0233. Under this option, the staff would select several doses and exclude from further consideration all individual doses below these levels. LCFs are only calculated for those individuals who received exposures that exceed the selected truncation dose.

This option offers the following advantages:

– It includes the LNT risk model and multiple truncation points. The LNT results would use the dose response model employed in previous offsite consequence analyses.

– It is consistent with the 2007 ICRP recommendations (Report 103) in that some of the estimates presented do not rely on the use of collective dose at low dose levels.

– Stakeholders might perceive the range of answers as providing the most complete information.

This option has the following disadvantages:

– It includes an estimate that calculates collective dose, including very small exposures to large population groups.

– Stakeholders could have difficulty understanding the use of different truncation values for assessing the LCF for the same scenario.

– The presentation of multiple results could be poor for risk communication purposes because it would not facilitate common understanding by stakeholders and would invite selective misinterpretation in both the possible underestimation and possible overestimation of offsite health consequences. That is, the results could be interpreted in various ways according to stakeholder viewpoints.

(2) Use only an LNT model to assess LCFs.

This option offers the following advantages:

– It could promote a common understanding among the stakeholders by providing a single consequence for each scenario analyzed.

– It would present the results using the dose response model used in previous consequence analyses.

– It is consistent with the recommendations in NCRP Report 121, "Principles and Application of Collective Dose in Radiation Protection," issued November 1995, and errata issued July 1996.

– It is consistent with the recommendations of the U.S. National Academies and UNSCEAR.

– It is consistent with the Commission's regulatory policy.

This option has the following disadvantages:

- It includes an estimate that calculates all doses, including very small exposures to large populations, which would be contrary to the statements of ICRP and the Health Physics Society (HPS) that such calculations are inappropriate.

- Stakeholders might perceive it as not providing the most complete information because it does not recognize the uncertainty in the dose response model at low doses.

(3) Estimate the number of LCFs using a single dose truncation value of 0.05 Sv (5 rem) per year or 0.1 Sv (10 rem) for a lifetime.

This option offers the following advantages:

- It could promote a common understanding among stakeholders by providing a single consequence for each scenario analyzed.

- It could be viewed as consistent with ICRP statements on the use of collective dose, although ICRP does not advocate a particular truncation value.

- It focuses attention where the observation of health effects may be more likely.

- It is consistent with the HPS position.

This option has the following disadvantages:

- It is not consistent with the previous practice of using an LNT model to estimate LCFs; hence, it does not present the results of the dose response model used in previous offsite consequence analyses.

- It is not consistent with NCRP recommendations regarding the use of collective dose to assess latent health effects (NCRP Report 121).

- Stakeholders may perceive it as advocating a threshold for LCF induction, even though it is intended only to facilitate the presentation of the most meaningful offsite consequences (it excludes those possible LCFs that would not be detectable).

- It excludes most of the collective dose from consideration; hence, stakeholders may perceive this alternative as not providing complete information.

(4) Estimate the number of LCFs using a single dose truncation value of 100 µSv (10 mrem) per year.

This option offers the following advantages:

- It could promote a common understanding among stakeholders by providing a single consequence for each scenario analyzed.
- It is consistent with the new ICRP recommendations (Report 103), which state that the computation of cancer deaths based on collective effective doses involving trivial exposures to large populations is not reasonable and should be avoided, although the ICRP did not advocate a particular truncation value.

- It is consistent with ICRP and International Atomic Energy Agency (IAEA) views on trivial exposure.

This option has the following disadvantages:

- It is not consistent with the previous practice of using an LNT model to estimate LCFs; hence, it does not present the results of the dose response model used in previous offsite consequence analyses.

- It is not consistent with NCRP recommendations regarding the use of collective dose to assess latent health effects (NCRP Report 121); hence, stakeholders may perceive this alternative as not providing complete information.

- It is not consistent with the HPS position that health effects attributable to radiation exposure should not be considered quantitatively below 0.05 Sv (5 rem) in a year or 0.1 Sv (10 rem) in a lifetime.

- It excludes some collective dose from consideration; hence, stakeholders may perceive this alternative as not providing complete information.

(5) Estimate the number of LCFs using both a linear dose response model and a single dose truncation value of 100 µSv (10 mrem) per year.

This option offers the following advantages:

- It would include the dose response model used in previous analyses and one truncation point.

- It is consistent with previous methodology, NRC regulatory policy, and recommendations of the National Academies, UNSCEAR, and World Health Organization (WHO) (for dose response).

- The use of a 100 µSv (10 mrem) dose truncation is broadly consistent with the new ICRP recommendations (Report 103) on the use of collective dose.

- The use of a 100 µSv (10 mrem) dose truncation is broadly consistent with ICRP and IAEA views on trivial exposure.

This option has the following disadvantages:

- The results of two separate assessments may be difficult to communicate to the public.

- It is not consistent with the HPS position that health effects attributable to radiation exposure should not be considered quantitatively below 0.05 Sv (5 rem) in a year or 0.1 Sv (10 rem) in a lifetime.

(6) Calculate the average individual likelihood of an early fatality and LCF that is expressed as the average probability of a population-weighted, average individual (age and gender averaged) dying from cancer conditional to the occurrence of a severe reactor accident. The calculation would include both LNT and 100 µSv (10 mrem) dose response models, with results presented for three distances: (1) 0 to 16.1 km (10 miles); (2) 0 to 80.5 km (50 miles); and (3) 0 to 161 km (100 miles).

This option offers the following advantages:

- It could facilitate public risk communication by providing a likelihood of consequences that could be compared with the occurrence of LCFs in the general population from causes other than a reactor accident.

- The distances selected are consistent with emergency planning zones and the agency's strategic planning goals.

- The use of the LNT model is consistent with previous consequence analyses and the Commission's regulatory policy.

- The use of a linear dose response model to assess LCFs is consistent with the recommendations of the U.S. National Academies and WHO.

- The truncation value of 100 µSv (10 mrem) is broadly consistent with the new ICRP recommendations (Report 103), which state that computation of cancer deaths based on collective effective doses involving trivial exposures to large populations is not reasonable and should be avoided.

- This approach also would be similar to that used by the Commission in establishing its Safety Goals.

This option has the following disadvantages:

- It is not consistent with SECY-05-0233, and the results use a metric that has been only a minor focus in previous analyses (used previously in Environmental Impact Statements).

- The full range of potential sensitivity may not be shown, if results are given for LNT and only a single truncation dose.

– It is not consistent with the HPS position that health effects attributable to radiation exposure should not be considered quantitatively below 0.05 Sv (5 rem) in a year or 0.1 Sv (10 rem) in a lifetime.

Upon receipt of Commission direction, and in conjunction with continuing SOARCA activities, the staff proposes to submit the methodologies and approaches used for the first two plants to a peer review. This review will enable the staff to have confidence that its methodologies are adequate for the objectives of the program.

Furthermore, the staff plans to discuss some details regarding the project methodology and some of the preliminary insights and findings from the initial assessments at the March 2008 Regulatory Information Conference. In accordance with Commission direction not to make the results publicly available until all SOARCA analyses have been completed, the staff will not discuss the preliminary results.

Conclusion

The staff considered a range of options for calculating LCFs and believes that the best approach is to use alternative (6). The calculation of the mean likelihood of a population-weighted, average individual dying from cancer conditional on the occurrence of a severe reactor accident provides a more direct comparison with the occurrence of cancer fatalities in the general population from causes other than a reactor accident.

In its letter dated February 22, 2008, the Advisory Committee on Reactor Safeguards (ACRS) recommends that consequences be expressed in terms of ranges calculated using 5 rem and some lower threshold, and that a calculation with LNT should also be performed to facilitate comparison with historical results. This recommendation is encompassed within alternative 1 in this paper. After a review of the strengths and weaknesses of each alternative, the staff believes that alternative 6 provides the best option for projecting latent cancer health effects in SOARCA. The staff's formal response to the ACRS will provide the Committee the basis for this approach, and address the additional recommendations provided by the ACRS in the February 22, 2008, letter.

The staff will need to address both scientific and communication issues in the presentation of the SOARCA results to stakeholders. The staff recognizes that a calculation of LCF using a linear model without dose truncation will be performed, if not by the NRC staff, then by others. If an NRC stakeholder rather than the NRC itself performs these calculations, the agency may need to expend significant resources in an attempt to explain what the NRC provided and why it was the most appropriate presentation. The staff will have to make clear that the presentation of any results based on dose truncation does not discount the possibility of LCFs at low doses and thereby may be an incomplete estimate of LCFs. That is, the staff recognizes that neither the use of a LNT model nor the selection of any particular truncation value for assessing LCF is supported by any specific scientific information regarding cancer induction. The staff will discuss the reasoning behind the selection of the 100 µSv (10 mrem) truncation value alongside the argument for considering a threshold in the portrayal of risk.

RECOMMENDATIONS:

The staff recommends that the Commission take the following two actions:

(1) Approve the recommended methodology for assessing offsite health consequences as the increased likelihood of an average individual dying of cancer from the occurrence of the severe accident scenario that meets the SOARCA screening criteria.

(2) Approve the recommendation to submit the Peach Bottom and Surry methodology and approaches for peer review by a cadre of experts who have not participated in the development of the SOARCA and who have expertise in one or more areas of the disciplines employed in the SOARCA.

COORDINATION:

The Office of the General Counsel reviewed this package and has no legal objection. The Office of the Chief Financial Officer reviewed this package and determined that it has no financial impact.

/RA/

Luis A. Reyes
Executive Director
for Operations

Enclosure:
Assessment of Latent Health Effects Attributable to Ionizing Radiation and Public Communication of Offsite Consequences

Assessment of Latent Health Effects Attributable to Ionizing Radiation and Public Communication of Offsite Consequences

Opinions differ among the staff of the U.S. Nuclear Regulatory Commission (NRC) as well as within the external scientific community regarding the dose response relationship between latent cancer mortality and exposure to low dose radiation (less than 0.10 sievert (Sv)(10 rem)). Experts also disagree regarding the existence, or absence, of a threshold in the dose response model and the application of dose truncation in the state-of-the-art reactor consequence analyses (SOARCA). This makes it difficult to decide how SOARCA should evaluate latent cancer fatalities (LCFs) from low doses to large populations. Finally, the staff recognizes the challenges in communicating offsite health consequence results to external stakeholders.

Which Dose Response Relationship Should Be Used?

Experts generally agree that it is difficult to characterize cancer risk for some tissue sites because of the low statistical precision associated with relatively small numbers of excess cases. This can limit the ability to estimate trends in risk. From an epidemiological standpoint, in most if not all cases, the LCF attributable to radiation exposure from accidental releases from a severe accident would not be detectable above the normal rate of cancer fatalities in the exposed population (i.e., the excess cancer fatalities predicted are too few to allow the detection of a statistically significant difference in the cancer fatalities expected from other causes among the same population). For example, in 2006, the World Health Organization (WHO) estimated that 16,000 European cancer deaths will be attributable to radiation released from the 1986 Chernobyl nuclear power plant accident, but these predicted numbers are small relative to the several hundred million cancer cases that are expected in Europe through 2065 from other causes. Furthermore, WHO concluded that, "it is unlikely that the cancer burden from the largest radiological accident to date could be detected by monitoring national cancer statistics."

New findings have been published from analyses of fractionated or chronic low dose exposure to low linear energy transfer (LET) radiation; in particular, a study of nuclear workers in 15 countries, studies of persons living in the vicinity of the Techa River in the Russian Federation who were exposed to radioactive waste discharges from the Mayak Production Association, a study of persons exposed to fallout from the Semipalatinsk nuclear test site in Kazakhstan, and studies in regions with high natural background levels of radiation. Cancer risk estimates in these studies are generally compatible with those derived from the Japanese atomic bomb data. Most recent results from analyzing these data are consistent with a linear or linear-quadratic dose response relationship of all solid cancers together and with a linear-quadratic dose response relationship for leukemia.

In the absence of additional information, the International Commission on Radiological Protection (ICRP), the U.S. National Academies, and the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) have each indicated that the current scientific evidence is consistent with the hypothesis that there is a linear, no threshold (LNT) dose response relationship between exposure to ionizing radiation and the development of cancer in humans.

Conversely, the French National Academy of Medicine, in "Dose-effect relationships and estimation of the carcinogenic effects of low doses of ionizing radiation," March 30, 2005, advocates the following:

> A linear no-threshold relationship (LNT) describes well the relation between the dose and the carcinogenic effect in this dose range (0.2 to 3 Sv) where it could be tested. However, the use of this relationship to assess by extrapolation the risk of low and very low doses deserves great caution. Recent radiobiological data undermine the validity of estimations based on LNT in the range of doses lower than a few dozen mSv which leads to the questioning of the hypotheses on which LNT is implicitly based.

While the French National Academy of Medicine raises doubts regarding the validity of using LNT for evaluating the carcinogenic risk of low doses (less than 100 millisieverts (mSv) (10 rem)) and even more so for very low doses (less than 10 mSv (1 rem)), it did not articulate what exact value should be ascribed to a dose threshold.

Is the Use of Collective Dose Appropriate for Predicting Latent Cancer Fatalities?

Ultimately, external and internal exposures to individual members of the public are converted from collective organ dose to LCFs using MACCS2. The LNT model raises the concern that the summation of trivial exposures may inappropriately attribute LCFs to individuals far from the site of the accident. While the possibility of LCF from very low doses cannot be ruled out, organizations such as ICRP and the Health Physics Society (HPS) consider it to be an inappropriate use of these exposures. While the National Council on Radiation Protection and Measurements (NCRP) supports the LNT model, it recommends binning exposures into ranges and considering those ranges separately. Furthermore, in situations involving trivial exposures to large populations, ICRP and NCRP have noted that the most likely number of excess health effects is most likely zero, when the collective dose to such populations is equivalent to the reciprocal of the risk coefficient (about 20 person-Sv (2000 person-rem)).

Nevertheless, issues remain related to assessing public exposure, estimating offsite consequences, and communicating these assessments to the public. Several organizations, such as ICRP, have addressed this issue. In its most recent recommendations (ICRP Report 103, "The 2007 Recommendations of the International Commission on Radiological Protection," approved March 2007), ICRP stated the following:

> (161) Collective effective dose is an instrument for optimisation, for comparing radiological technologies and protection procedures. Collective effective dose is not intended as a tool for epidemiological studies, and it is inappropriate to use it in risk projections. This is because the assumptions implicit in the calculation of collective effective dose (e.g., when applying the LNT model) conceal large biological and statistical uncertainties. Specifically, the computation of cancer deaths based on collective effective doses involving trivial exposures to large populations is not reasonable and should be avoided. Such computations based on collective effective dose were never intended, are biologically and statistically very uncertain, presuppose a number of caveats that tend not to be repeated

> when estimates are quoted out of context, and are an incorrect use of this protection quantity.

Although ICRP provided qualitative guidance regarding situations where collective dose should not be used, it did not provide guidance regarding when these concepts actually are, and are not, appropriate, nor did it clearly articulate the boundary conditions within which the calculations are valid, as well as the dose ranges for which epidemiological and cellular or molecular data provide information on the health effects associated with radiation exposure. ICRP did note, however, that when ranges of exposures are large, collective dose may aggregate information inappropriately and could be misleading for selecting protective actions.

How Should Low Dose Consequences Be Estimated?

The National Academies reported the following:

> The magnitude of estimated risk for total cancer mortality or leukemia has not changed greatly from estimates in past reports such as Biological Effects of Ionizing Radiation (BEIR) and recent reports of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) and ICRP. New data and analyses have reduced sampling uncertainty, but uncertainties related to estimating risk for exposure to low doses and dose rates and to transporting risks from Japanese A-bomb survivors to the U.S. population remain large.

The National Academies go on to conclude that, “current scientific evidence is consistent with the hypothesis that there is a linear, no-threshold dose-response relationship between exposure to ionizing radiation and the development of cancer in humans.”

Many groups acknowledge the uncertainties associated with estimating risk for exposure to low radiation doses. The question that remains is what offsite health consequences are attributable to very low radiation exposure. In its most recent recommendations (ICRP Report 103), described above, ICRP warned that the computation of cancer deaths based on collective effective doses involving trivial exposures is not reasonable and should be avoided, but it did not explicitly state which exposures should not be considered. However, in ICRP Report 104, “Scope of Radiological Protection Control Measures” (in press), ICRP concludes that the radiation dose that is of no significance to individuals should be in the range of 20–100 microsieverts (μSv) (2–10 millirem (mrem)) per year whole body dose. The International Atomic Energy Agency (IAEA) has stated that an individual dose is likely to be regarded as trivial if it is of the order of some several millirem per year. Although there is no scientific basis for defining a trivial dose, the ICRP and IAEA definitions of trivial dose may provide a basis to address truncation of offsite radiation exposure and attributable health consequences.

Alternatively, HPS developed a position paper, “Radiation Risk in Perspective,” revised August 2004, to specifically address quantitative estimation of health risks. This position paper concludes that quantitative estimates of risk should be limited to individuals receiving a whole body dose of 0.05 Sv (5 rem) in 1 year or a lifetime dose of 0.1 Sv (10 rem), in addition to natural background. HPS also concluded that risk estimates should not be conducted below these doses. The position paper further states that low dose expressions of risk should only be qualitative, discusses a range of possible outcomes, and emphasizes the inability to detect any increased health detriment. The difference between the HPS view and those expressed by ICRP and IAEA is the detectability of an offsite consequence versus exposure to trivial doses.

<u>Are there Staff Concerns about Estimating Latent Cancer Fatalities?</u>

As discussed above, the LNT model provides a viewpoint that is consistent with the regulatory approach of the agency. The NRC uses this model to calculate LCFs for regulatory purposes. Furthermore, past analyses using the MACCS2 code have assumed an LNT dose response model. In addition, past analyses calculated LCFs to 1,000 miles with forced deposition to account for all nonnoble gas radionuclides in the dose calculation. Therefore, if use of the dose response model of past analyses is desired, continued use of the LNT model without any dose truncation is necessary.

As a matter of policy, however, the NRC can use different approaches for different applications. The use of a truncation dose criterion would not necessarily impact the underpinnings of the agency's regulatory defense-in-depth approach to protect public health and safety, which is based on an LNT model. Any future SOARCA reports could emphasize that the NRC is not changing or contemplating changing radiation protection standards and policy as a result of an approach taken in this study to characterize offsite health consequences for low probability events. Regarding comparison with previous studies, the benefit gained by performing calculations using the LNT model without dose truncation, which would allow comparison on the same methodological basis, has to be weighed against the disadvantages of using such a collective dose model in what the agency intends to be a state-of-the-art model.

The SOARCA Steering Committee and some NRC staff expressed concern that the health consequence estimations conducted by MACCS2 are dominated by small exposures to large numbers of individuals where the health effects are statistically very uncertain. Furthermore, these staff members are concerned about their inability to present these offsite consequences in a context that compares SOARCA results with the existing rates of cancer mortality among the exposed resident population. To address these concerns, it was proposed that exposures to the public could be truncated to exclude all LCFs attributable to exposure less than some selected value (Figure 1).

On the other hand, other NRC staff are concerned that some NRC stakeholders will perceive the truncation of exposure, even exposures above a trivial dose, and the subsequent exclusion of offsite health consequences as disingenuous in that many individual exposures (and some future LCFs) will be arbitrarily, or deliberately, excluded from consideration and will not be reported as an offsite consequence. These staff members believe that this could significantly undermine public confidence in the NRC's ability to objectively evaluate and report offsite consequences and thus impartially regulate the civilian use of nuclear materials. Furthermore, the need to defend a truncation value may obscure the technically justified changes that have been made in the source term and offsite consequence model used in SOARCA.

<u>What Is the Staff's Recommendation for Assessing Offsite Health Consequences?</u>

National and international radiation protection organizations provide little or no policy guidance that addresses how individual effective dose and collective dose can be assessed and used to estimate LCFs after low dose radiation exposure. In the absence of guidance, the NRC conducted a survey of staff health physics and radiation biology experts.

To aid the staff's evaluation of offsite health consequences, respondents evaluated a screened nuclear power plant accident for two power reactor sites. They assessed the potential occurrence of early fatality and LCFs. No early fatalities attributable to acute radiation sickness were predicted for either site. However, a number of LCFs might potentially occur depending on the dose truncation value selected. LCFs were estimated using truncation values ranging from 0 to 0.05 Sv (5 rem). For each truncation value, the LCFs were averaged and plotted as percent LCF versus dose (Figure 2). Selection of a 100 μSv (10 mrem) dose truncation reduced the number of estimated LCFs by approximately 40 percent. Truncation at 0.001 Sv (100 mrem) and 0.01 Sv (1 rem) reduced the number of estimated LCFs by 80 percent and 90 percent, respectfully. Virtually no LCFs are estimated with truncation at 0.05 Sv (5 rem) or more. Figure 2 illustrates that truncating doses even at very small values, for example 10 μSv (1 mrem), can reduce the aggregation of small doses to many individuals, thus reducing the estimated number of potential cancer deaths.

These experts considered the following five alternative methods for assessing offsite LCFs:

1. Use a range of dose truncation values, from 0 to 0.05 Sv (5 rem).

2. Use only an LNT model.

3. Estimate the number of LCFs using a single 0.05 Sv (5 rem) per year, 0.1 Sv (10 rem) lifetime dose truncation value.

4. Estimate LCF using a single 100 μSv (10 mrem) per year dose truncation value.

5. Estimate LCF using a linear dose response model with and without a single dose truncation value.

The respondents specified their recommended truncation values and provided their reasoning for their selection.

There was little expert support for assessing LCF using just an LNT dose response or truncating dose based on 0.05 Sv (5 rem) per year or 0.1 Sv (10 rem) lifetime. The expert group did not broadly endorse the 0 to 0.05 Sv (5 rem) range of dose truncation values proposed in SECY 05-0233, "Plan for Developing State-of-the-Art Reactor Consequence Analyses," dated December 22, 2005. The majority supported the alternative to estimate LCF using an LNT model and a linear model with a single truncation. The values suggested for truncation generally ranged from 10 μSv to 0.001 Sv (1 to 100 mrem). Half of these respondents favored values between 1 and 10 mrem because these most closely represent a trivial exposure. The other respondents favored values between 25 and 100 mrem because these most closely represent the public dose limit and source constraints on radiation exposure. The maximum value proposed for this alternative was 500 mrem. The central value was estimated to be approximately 10 mrem.

During a SOARCA Steering Committee meeting to discuss this issue, alternative (6) was suggested, using a different metric:

6. Estimate a population-weighted individual likelihood of LCF with and without a single dose truncation value for different distances from the plant. The calculation would include both LNT and 100 µSv (10 mrem) dose response models with results presented for three distances: (1) 0 to 16.1 km (10 miles); (2) 0 to 80.5 km (50 miles); and (3) 0 to 161 km (100 miles).

This metric is not new; past Environmental Impact Statements have used it (see, for instance, NUREC-0537, “Final Environmental Impact Statement Related to the Operation of Midland Plant, Units 1 and 2,” issued July 1982). Furthermore, this approach is similar to the one The Commission used in establishing its Safety Goals. The metric has the advantage of facilitating public risk communication by providing a likelihood of consequences that could be compared with the occurrence of LCFs in the general population from causes other than a reactor accident. The staff’s best estimate of offsite LCFs would be the assessment with the 100 µSv (10 mrem) truncation value because it would limit the overaggregation of very small exposures to many individuals. Comparison of this value with the nontruncated estimate will provide a general indication of how much small population doses impact the estimation of offsite consequences.

Conclusion

The staff recommends using alternative (6) for estimating LCF for screened nuclear power reactor severe accidents.

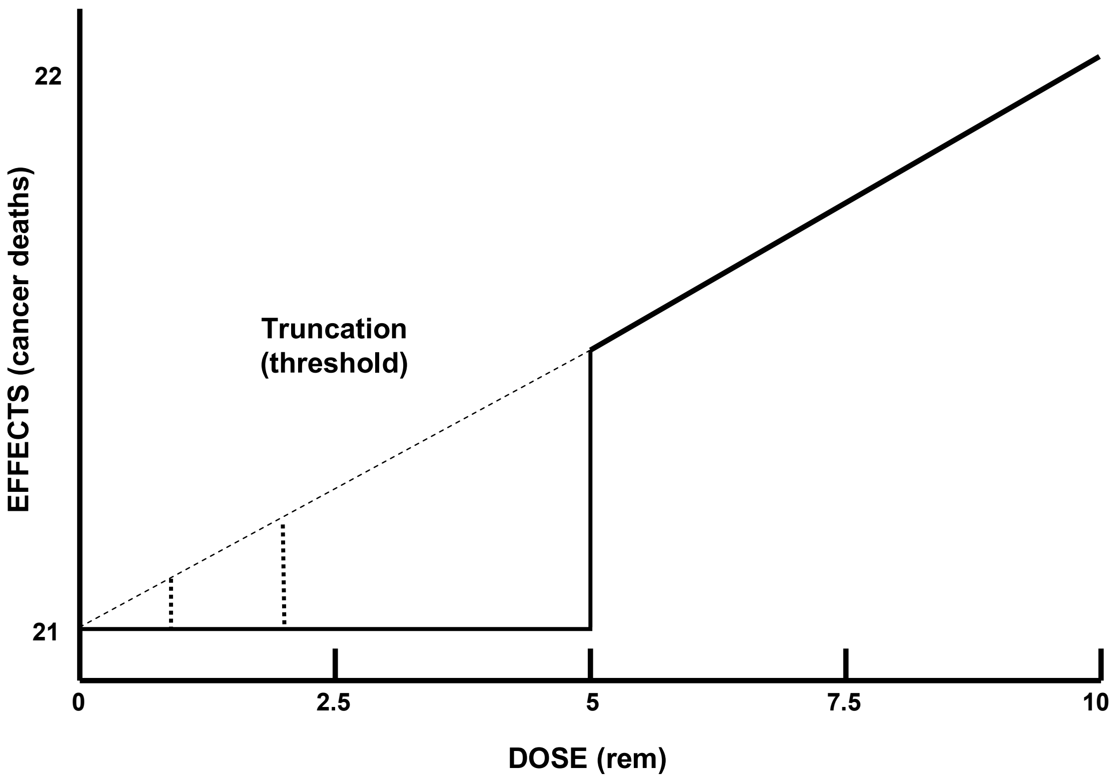

Figure 1 - Estimation of LCFs using a linear dose response model and dose truncation from 0 to 0.05 Sv (5 rem)

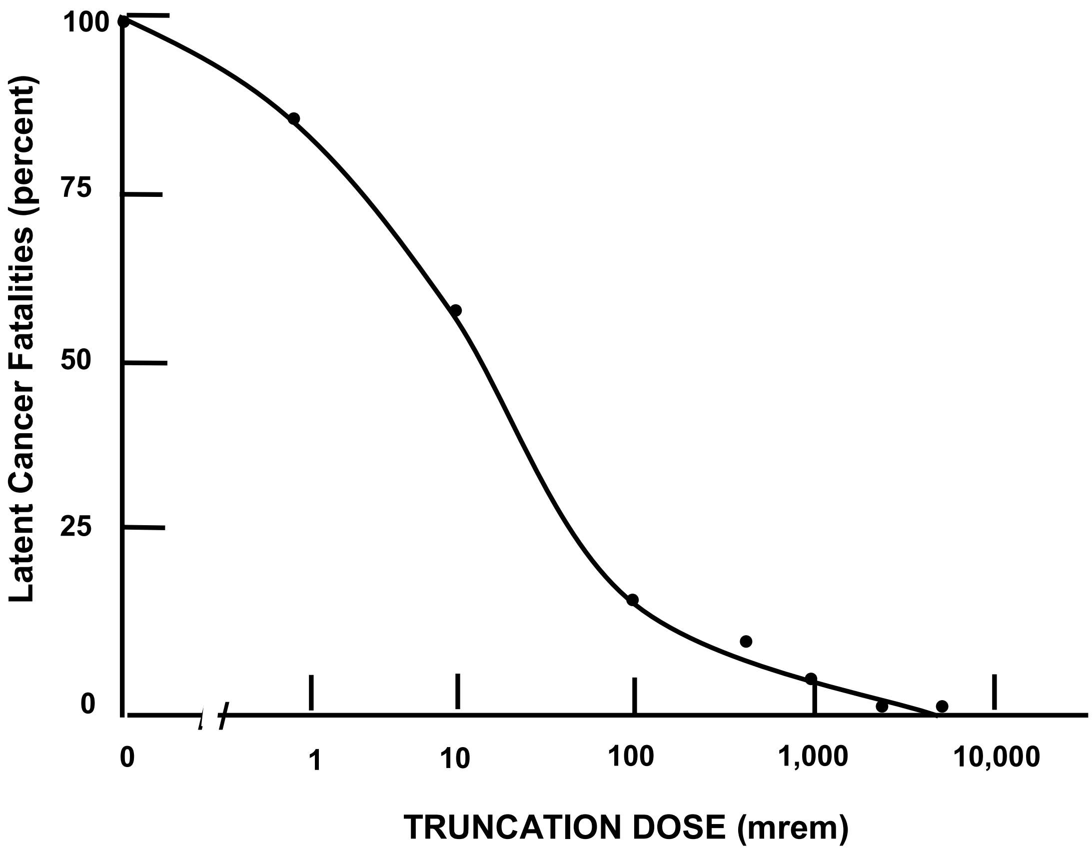

Figure 2 - Average sensitivity for LCF within 1000 miles of a nuclear power reactor