MEMO

Re: Guidance on SOARCA Issues as Requested in the March 2-3, 2010 Meetings

To: SOARCA Team

Through: S. P. Burns

From: K. Vierow
Chair, SOARCA Peer Review Committee*

Date: April 9, 2010

During the March 2-3, 2010 meetings on the SOARCA project, issues arose for which the SOARCA Peer Review Committee members were requested to provide guidance to support post-meeting work efforts. As guidance was requested prior to completion of the Committee's final report, responses are being transmitted in memo format. There was no attempt to arrive at a consensus or influence any individual peer reviewer's opinions.

The Committee members' comments and suggestions are provided below in italic font for consideration by the SOARCA team.

1. Does the Committee have recommendations on how the information regarding dose limits presented by Jacquelyn Yanch may be included in the SOARCA report?

   Jacquelyn Yanch and David Leaver have provided the following comments.

   Use of the current "return home" (i.e., long-term habitability) dose limits certainly seems to be "state-of-the-art" since the individual states and government agencies all use dose limits that are in a similar range. Therefore the SOARCA study is, indeed, reflecting the state of the art.

   However, the fact remains that all of these dose limits (i) are based on very poor data, and (ii) are low in terms of doses and dose rates we currently receive in other applications (e.g. medical doses and elevated natural background areas). For example, the return home dose limit of 500 millirem per year in most states compares with doses from typical computed tomography (CT) scans in excess of 500 millirem, with over 70 million CT scans per year now being performed in the U.S. The average dose rate represented by the return home criterion of 500 millirem in one year is below the natural background dose rate in many parts of the world, and is less than a factor of two above natural background dose rates in the United States.

   There is the concern that society will struggle to try to meet these dose limits by trading off important activities related to returning home, accessing contaminated land, etc. This trade-off might make sense if we were confident we knew the biological effect of these

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doses and dose rates, but we are far from confident and in fact the data are associated with very large uncertainties. Thus, one of the consequences of a severe reactor accident might be the chaos (social and economic) that ensues as we try to get life back to normal after the accident. We, as a society, should address this issue before something happens rather than afterwards, especially given the very long latent period of radiation-induced cancer. Since this is potentially a major issue, it would be very good to have some aspect of this highlighted in the SOARCA NUREG.

Jeff Gabor supports inclusion of Jacquelyn Yanch's comments in the SOARCA documents.

Roger Kowieski does not believe that the information regarding the dose limits presented by Jacquelyn Yanch belongs in the SOARCA document.

The U.S. Environmental Protection Agency manual, EPA 400-R-92-001, dated October 1991, provides guidance for implementing the Protective Action Guides (PAGs) by State and local officials during the early phase of a nuclear incident, as well as, long term recovery operations. The PAGs for protection of the public from deposited radioactivity are well documented, and the bases for these values are summarized in this manual. This document recognizes that the relocation is the most effective, and, usually, the most costly and disruptive. It is therefore only applied when the dose is sufficiently high to warrant it. In conclusion, it is suggested that any comments/concerns regarding the recommended PAGs (dose limits) be addressed to the Office of Radiation Programs, U.S. Environmental Agency, Washington DC 20460.

Ken Canavan and Karen Vierow suggest that the information regarding the low magnitude of the dose limits is appropriate in the SOARCA documents but the discussion of dose limit validity belongs elsewhere.

Demonstration that health risks resulting from radioactive releases at the currently accepted dose limits are very low is a compelling argument for the safety of nuclear power plants. However the discussion of the validity of current state-of-the-art dose limits should be directed, as Roger Kowieski recommends, to a party that could address this issue. The SOARCA consequence analyses show that health risks for lower dose limits are also very small in magnitude, negating a need for discussion of an appropriate dose limit within the SOARCA project.

2. Which source of dose conversion factors is most appropriate for use in SOARCA? Is Federal Guidance Report 13 up to date? Is BEIR V best-estimate? Are MACCS2 calculations with other dose conversion factors needed? These calculations could be included in the Uncertainty Study.

Kevin O'Kula provided the following comments on Federal Guidance Report 13.

Federal Guidance Report (FGR) 13 dose conversion factors (DCFs) are the most appropriate for use in the SOARCA program. FGR 13 DCFs represent the culmination of considerable work by Keith Eckerman and colleagues at ORNL to maintain a high-

pedigree data set that reflects current models and available bio-dosimetric data. No value is found in applying other, or older, sets of DCF input data in the SOARCA calculations. Therefore, only FGR 13 DCFs are recommended.

Jacquelyn Yanch has provided a comparison of BEIR V and BEIR VII risk estimates in the attached memo.

For the SOARCA study, she recommends the use of BEIR VII risk estimates, rather than those of BEIR V, based on the results of this comparison.

3. Is the comparison of SOARCA calculations using the SST1 source term and the SOARCA source term fair and not misleading?

Jeff Gabor, Bob Henry, Dave Leaver, Karen Vierow and Jacquelyn Yanch provided the following comments.

The technologies used in the studies could be compared for the same weather scenarios as this would reflect the accomplishments in radiological source term analysis methodologies over the past 30 years. Chapter 7 in Appendices A and B draws appropriate conclusions from the comparison, specifically, that the SST1 source term is larger than the SOARCA best-estimate source term and that "This reflects improvements in understanding and modeling capabilities developed since the Sandia Siting Study was conducted."

The health effect risks should not be compared since the Sandia Siting Study consequence analysis methodology and assumptions, unlike SOARCA, are not consistent with today's understanding of radiation health risks.

4. Is SOARCA justified in reporting results at the 50-mile limit?

Jeff Gabor, Dave Leaver, Kevin O'Kula and Jacquelyn Yanch state that the technical basis for reporting results to a distance of fifty miles is justified.

Although earlier PRA analyses may have used longer consequence base model distances, the fifty-mile grid is supported by the following arguments:

- *Current plant license renewal and new design considerations in quantifying cost/benefits of severe accident mitigation alternatives (SAMA) analysis and severe accident mitigation design alternatives (SAMDA) are based on consequences to a 50-mile region. Guidance for performing SAMA analyses is provided in NRC staffed-approved NEI 05-01, Rev. A, Severe Accident Mitigation Alternatives (SAMA) Analysis Guidance Document, and uses a 50-mile basis.*
- *The Ingestion Planning Zone (IPZ) around current and proposed plants, and used as a basis for evaluation in Environmental Impact Statements (EISs), is fifty miles.*
- *In Regulatory Analysis Guidelines of the U.S. Nuclear Regulatory Commission, NUREG/BR-0058, Revision 4, (September 2004), it is stated:*

"In the case of nuclear power plants, changes in public health and safety from radiation exposure and offsite property impacts should be examined over a 50-mile distance from the plant site" (p. 29).

- *The individual risk decreases rapidly with distance and is extremely low a short distance from the site boundary (i.e., well over a factor of 1000 below the NRC latent cancer QHO inside 10 miles). However, reporting individual risk results to 50 miles is reasonable for completeness and to show the trend of decreasing risk with increasing distance.*

These peer reviewers recommend that the current discussion in the Summary Document be augmented to better support the application of the 50-mile basis.

Kevin O'Kula added the following clarification.

The SOARCA analysis, and indeed, a PRA, is concerned with a nuclear plant and its operations, and not just the reactor. It should be noted that this is a study of the full plant response to specific postulated accident conditions.

5. Does the Committee have recommendations on future work for SOARCA?

Jeff Gabor, Bob Henry, Dave Leaver, Kevin O'Kula, Karen Vierow and Jacquelyn Yanch provided the following comments.

a. *Full Level 3 PRA*
The SOARCA has evaluated the scenarios which are the major contributors to risk. In this manner, SOARCA is a partial Level 3 PRA and it has provided much data that would be obtained from a full Level 3 PRA, making a full Level 3 PRA less necessary

The results of a full Level 3 PRA would be specific to the nuclear power plant (NPP) for which it was performed; therefore Level 3 PRA results cannot be applied to other NPPs. Conversely, a SOARCA for one plant provides insights for other plants of the same type. If SOARCA-level analyses for other NPP types are conducted and the results do not change greatly, then a full Level 3 PRA can be considered unnecessary for achieving the goals of SOARCA Project.

Ken Canavan goes further to suggest that, as part of future work, the SOARCA team consider a partial or full Level 3 PRA.

There is the possibility that certain accident sequences, while not-dominant from a frequency basis, may have relative high risk due to high consequence. While these sequences may not dominant the risk, in terms of frequency and consequence, they could be contributors. Collections of several lower order sequences, while individually non-dominate, could have higher consequence than SOARCA evaluated and could contribute to the risk collectively. While SOARCA did indeed capture the most likely sequences and accurately capture the consequence from these sequences, the primary issue with consequence analyses of this type is that it is difficult to *demonstrate completeness. A Level 3 PRA performed for the SOARCA plant could have the benefit of reduced resources (due to work performed for SOARCA) as well as the benefits of validation of the SOARCA approach and demonstration of completeness. For these reasons, a Level 3 PRA for the SORCA plant might have some value.*

Bernard Clement is of the opinion that full Level 3 PRAs are of great interest, independently of SOARCA.

b. *SOARCAs for other plants*
These peer reviewers recommend that SOARCAs be conducted for other NPP types with different containment designs. The change in results from one NPP type to another should be investigated. As mentioned above, if the results do not vary greatly, a full Level 3 PRA would probably be unnecessary.

Regarding the selection of plant types, the remaining plants from the five considered for NUREG-1150 reactors or a down-selection from the eight reactor types that the NRC originally considered would be reasonable.

John Stevenson recommends an evaluation of plant foundation conditions.

Plant foundation conditions at the Surry Site indicate the potential for liquification and consolidation due to earthquake at the SOARCA very low earthquake probabilities of exceedence. This may be considered as a-follow-on SOARCA effort.

c. *Statement on the scope of SOARCA*
Several consequences of a severe accident have not been evaluated within the context of the SOARCA project. These include land contamination, economic losses and recovery costs. A statement should be made in the SOARCA documentation that they are beyond the scope of SOARCA.

Other than as commented in items 1 and 5, Ken Canavan concurs with the memo.

Other than as commented in item 1, Roger Kowieski concurs with the memo.

Bruce Mrowca has not provided an opinion.

John Stevenson wrote the following statement, which is applicable to this memo except for item 5.b. "For the other areas where you have requested input from the Peer Group, I consider them outside my areas of expertise so I am not commenting on them."

*SOARCA Peer Review Committee Members:
Ken Canavan
Bernard Clement
Jeff Gabor

Robert Henry
Roger Kowieski
David Leaver
Bruce Mrowca
Kevin O'Kula
John Stevenson
Karen Vierow
Jacquelyn Yanch

Memorandum:

Re: Choice of Risk Estimates (Is BEIR V "best estimate"?)

To: Karen Vierow, Chair, SOARCA Peer Review Committee
Shawn Burns, SOARCA Study Team

From: Jacquelyn C. Yanch
Member, SOARCA Peer Review Committee

Date: 9 March 2010

The current analysis of late cancer fatality risk in the SOARCA study is based on use of BEIR V (1990) risk estimates. BEIR V estimates of radiation-induced cancer risk do not incorporate a low dose, low dose-rate effectiveness factor (DDREF) which would make the risk estimates applicable to situations where individuals are exposed continually and at a low dose rate. On the other hand, risk estimates published in BEIR VII (2006) do incorporate a DDREF and use a value of 1.5. That is, the risk estimates generated from a review of the Life Span Study population (A-bomb survivors) are reduced (divided by 1.5) to account for the sparing effect that might be expected if the same doses were delivered at a lower dose-rate.

The BEIR VII document asserts that the risk estimates from BEIR V and BEIR VII are similar, but only if the DDREF value of 1.5 is applied to the BEIR V data. Comparisons of BEIR V and BEIR VII estimates are made in Tables 12-8 and 12-9 of the BEIR VII report (pages 282-3); these tables are reproduced below. [To facilitate comparison with BEIR VII, the BEIR V estimates are shown as published, and then again divided by a DDREF of 1.5; these modified data appear in parentheses.]

Also shown in Tables 12-8 and 12-9 are the risk estimates generated by the ICRP, the EPA, and by UNSCEAR. The ICRP and EPA estimates include a DDREF of 2. UNSCEAR and BEIR V include no DDREF and neither document provides guidance for modifying the risk estimates to apply to situations involving low doses and/or low dose-rates.

Recommendation:
Given that exposure to radiation following a reactor accident will generate low doses delivered at low dose-rates, the use of a DDREF is warranted. For the SOARCA study, therefore, use of BEIR VII risk estimates, rather than those of BEIR V, is recommended. This recommendation is based on (i) the incorporation of a DDREF in BEIR VII, making the risk estimates more applicable to the post-accident irradiation scenario, and (ii) the 'best estimate' nature of the BEIR VII estimates which are based on an additional twelve years of follow-up of the Life Span Study population (relative to BEIR V). Use of a DDREF is also consistent with the approach adopted in Federal Guidance Report 13 in which a DDREF of 2 is used in the generation of risk estimates.

International Commission on Radiological Protection (1999) Risk Estimation for multifactorial diseases. Ann. ICRP 29:1-144.

United Nations Scientific Committee on Effects of Atomic Radiation (2000) Sources and Effects of Ionizing Radiation. UNSCEAR Report to the General Assembly.

Environmental Protection Agency (1994) Estimating Radiogenic Cancer Risks, EPA Report 402-R-93-076. Washington DC: Environmental Protection Agency.

National Research Council (1990). Health Effects of Exposure to Low Levels of Ionizing Radiation (BEIR V). Washington DC: National Academy Press.

National Research Council (2006). Health Effects of Exposure to Low Levels of Ionizing Radiation (BEIR VII). Washington DC: National Academy Press.

EPA (1999) Cancer Risk Coefficients for Environmental Exposure to Radionuclides. Federal Guidance Report No.13.

Tables from BEIR VII report (National Academy of Sciences) 2006, pages 282 and 283.

TABLE 12-8 Comparison of BEIR VII Lifetime Cancer Mortality Estimates with Those from Other Reports

Cancer Category	BEIR V[a] (NRC 1990)	ICRP[b] (1991)	EPA[b] (1999)	UNSCEAR[c] (2000)		BEIR VII[d]
Leukemia[e]	95 50	56	50			61
All cancer except leukemia (sum)	700 (460)	450	520			
All solid cancers (sum)				1150, 780 1400[f], 1100[f]	(520)	510
Digestive cancers	230 (150)					
Esophagus		30	12	30, 60	(25)	
Stomach		110	41	15, 120	(18)	22
Colon		85	100	160, 50	(75)	61
Liver		15	15	20, 85	(20)	16
Respiratory cancer	170 (110)					
Lung		85	99	340, 210	(160)	210
Female breast[g]	35 (23)	20	51	280, 65	(43)	37
Bone		5	1	—		
Skin		2	1	—		
Prostate[g]						5
Uterus[g]						3
Ovary[g]		10	15			12
Bladder		30	24	40, 20	(22)	25
Kidney		—	5	—		
Thyroid		8	3	—		
Other cancers or other solid cancers[h]	260 (170)	50	150	280, 180	(160)	130

NOTE: Excess deaths for population of 100,000 of all ages and both sexes exposed to 0.1 Gy.

[a]Average of estimates for males and females. The measure used was the excess lifetime risk; unlike other estimates in this table, radiation-induced deaths in persons who would have died from the same cause at a later time in the absence of radiation exposure are excluded. The estimates are not reduced by a DDREF, but parentheses show the result that would be obtained if the DDREF of 1.5, used by the BEIR VII committee, had been employed.

[b]Except for the EPA breast and thyroid cancer estimates, the solid cancer estimates are linear estimates reduced by a DDREF of 2.

[c]Average of estimates for males and females. Except where noted otherwise, estimates are based on the attained-age model. The first estimate is based on relative risk transport; the second on absolute risk transport. The estimate in parentheses is a combined estimate (using the same weights as used by the BEIR VII committee applied on a logarithmic scale) reduced by a DDREF of 1.5, although these were not recommendations of the UNSCEAR committee.

[d]Average of the committee's preferred estimates for males and females from Table 12-5B.

[e]Estimates based on a linear-quadratic model.

[f]Estimates based on age-at-exposure model.

[g]These estimates are half those for females only.

[h]These estimates are for the remaining solid cancers.

TABLE 12-9 Comparison of BEIR VII Lifetime Sex-Specific Cancer Incidence and Mortality Estimates with Those from Other Reports

	Males			Females		
Cancer Category	BEIR V[a]	UNSCEAR[b]	BEIR VII[c]	BEIR V[a]	UNSCEAR[b]	BEIR VII[c]
Incidence						
Leukemia[d]	NA	50	100	NA	50	72
All solid cancer	NA	1330, 1160 (740) 2600,[e] 1700[e]	800	NA	3230, 1700 (910) 3800,[e] 2100[e]	1310
Mortality						
Leukemia[d]	110	50	69	80	60	52
All cancer except leukemia (sum)	660 (440)			730 (490)		
All solid cancers (sum of sites)		710, 620 (380) 900,[e] 900[e]	410		1580, 930 (660) 1900,[e] 1300[e]	610

NOTE: Excess deaths for population of 100,000 of all ages exposed to 0.1 Gy.

[a]The measure used was the ELR; unlike other estimates in this table, radiation-induced deaths in persons who would have died from the same cause at a later time in the absence of radiation exposure are excluded. The estimates are not reduced by a DDREF, but parentheses show the result that would be obtained if the DDREF of 1.5, used by the BEIR VII committee, had been employed.

[b]Except where noted otherwise, estimates are based on the attained-age model. The first estimate is based on relative risk transport; the second on absolute risk transport. The estimate in parentheses is a combined estimate (using the same weights as used by the BEIR VII committee applied on a logarithmic scale) reduced by a DDREF of 1.5, although these were not recommendations of the UNSCEAR committee.

[c]Estimates are from Tables 12-6 and 12-7, and are shown with 95% subjective confidence intervals.

[d]Estimates based on a linear-quadratic model.

[e]Estimates based on age-at-exposure model.