

## ***A.11.0 Cancer Morbidity Risk Coefficients***

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### ***A.11.1 Description***

Cancer Morbidity Risk Coefficients were used with IEFs to calculate the RRF. The radionuclide risk factor is multiplied by the daily flux (i.e., rate of release) of each radionuclide to calculate the annual contribution to excess cancer risk from radionuclides ingested and retained in the body from food. The CMRC is described in the following sections.

### ***A.11.2 Current Knowledge***

The CMRC (formerly termed cancer slope factor) is the central estimate in a linear model of lifetime radiation-induced cancer incidence (i.e., the expected cancer rate per unit [pCi]) of radionuclide absorbed by the body. The CMRCs are empirically derived from public health data and cancer risk models developed and approved by several government and international organizations. The risk models assume that the risk of cancer is proportional to the radionuclide dose. The CMRCs are adjusted for the fraction of radionuclide ingested that is retained by the body and for the variation of risk with age, gender, and target organ. They are intended to estimate risks over a 70-year exposure. Therefore, they apply to both children and adults. CMRCs for all of the radionuclides of potential concern are published by EPA (2001). They are presented in Table A-9.

### ***A.11.3 Discussion of Uncertainties***

There are unknowns in the derivation of cancer morbidity risk coefficients from reported cancer rates and modeled exposures (Eckerman et al. 1999). The EPA recognizes that the CMRCs include both uncertainty and variability, but no quantitative uncertainty was stated (Eckerman et al. 1999). The CMRC is a central tendency that is recommended by U.S. EPA for this type of screening risk assessment.

### ***A.11.4 Implementation***

The CMRCs presented in Table A-9 along with annual IEFs (see Table 4 in the main text) were used to calculate the radionuclide risk factor for annual risk of excess cancers from ingestion of radionuclides (see Table 5 in the main text).

**Table A-9  
Cancer Morbidity Risk Coefficients for Radionuclides  
Selected for Screening Risk Assessment Modeling**

Radionuclide	Cancer Morbidity Risk Coefficient (pCi <sup>-1</sup> )	Radionuclide	Cancer Morbidity Risk Coefficient (pCi <sup>-1</sup> )
Tritium	$6.51 \times 10^{-14}$	<sup>152</sup> Gadolinium	$8.70 \times 10^{-12}$
Carbon-14	$2.00 \times 10^{-12}$	<sup>234</sup> Uranium	$9.55 \times 10^{-11}$
Chlorine-36	$4.44 \times 10^{-12}$	<sup>236</sup> Uranium	$9.03 \times 10^{-11}$
Strontium-90	$6.88 \times 10^{-11}$	<sup>238</sup> Uranium	$8.66 \times 10^{-11}$
Yttrium-90	$2.65 \times 10^{-11}$	<sup>237</sup> Neptunium	$8.29 \times 10^{-11}$
Technetium-93	$4.00 \times 10^{-12}$	<sup>239</sup> Plutonium	$1.74 \times 10^{-10}$
Iodine-129	$3.22 \times 10^{-10}$	<sup>240</sup> Plutonium	$1.74 \times 10^{-10}$
Cesium-137	$3.74 \times 10^{-11}$	<sup>241</sup> Plutonium	$2.28 \times 10^{-12}$
Samarium-151	$8.07 \times 10^{-13}$	<sup>241</sup> Americium	$1.34 \times 10^{-10}$
Europium-152	$8.70 \times 10^{-12}$		

## **A.12.0 Limits to Cancer Risk**

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### **A.12.1 Description**

The upper limit of radionuclide exposure is an amount of radionuclides that should result in a very small risk of cancer in addition to the risk from background radiation, fallout, and chemical exposures. The risk of radiation-induced cancer is thought to be proportional to the total dose of radionuclides. Therefore, establishing a limit to cancer risk is necessary to determine whether the risk from radionuclide flux is below a threshold for safety.

### **A.12.2 Current Knowledge**

For this assessment, limits to lifetime excess cancer risk must be chosen. There are no published rules that establish an acceptable cancer risk, in part because persons who are exposed may not consider any risk acceptable if it does not result from their chosen lifestyle. However, EPA generally does not require remediation of a site where the combined cancer risk is below one excess cancer case in 10,000 persons (EPA, 1990a and 1998). This risk is expressed as the number  $1 \times 10^{-4}$ . A lower lifetime risk of one excess contamination-caused cancer case in 1 million persons is considered to be below the level of concern (EPA, 1990a and 1998) because the frequency of cancer morbidity from all causes is several orders of magnitude higher. This risk is expressed as the number  $1 \times 10^{-6}$ . If the calculated lifetime cancer morbidity risk from the release of radionuclides is below  $1 \times 10^{-6}$ , it is inferred that cancer risk from the radionuclides is negligible.

### **A.12.3 Discussion of Uncertainties**

No quantitative value can be put on uncertainty associated with the threshold of  $1 \times 10^{-6}$ , but some observations are offered here for perspective.

- The U.S. EPA routinely uses a cutoff value of  $1 \times 10^{-6}$  (one per million persons exposed) as a value below which risk is so negligible that it does not need to be considered further.
- Studies of risks to subsistence consumers of fish in the Barents Sea (NDE, 2002) and the Kara Sea (ONR, 1997) from radionuclides dumped as nuclear waste suggest cancer risks in the range of about  $1 \times 10^{-8}$  to about  $3 \times 10^{-7}$ . These risks, which are estimated for waste dumped for several years directly into the sea or carried downriver from dump sites near the sea, are higher than any of the base-case results for Scenarios 1 through 9.

#### **A.12.4 Implementation**

A lower-limit lifetime cancer risk of  $1 \times 10^{-6}$  was used as the risk threshold below which it will be inferred that cancer risk is negligible.

## ***A.13.0 Calculation of Risks***

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The final output of the previous series of steps is the RRF. One uses the annual IEFs (Section A.9.0), fraction of contaminated diet (Section A.10.0), and the CMRCs (Section A.11.0) to calculate RRFs. The equation for RRF is  $(\text{risk/year per pCi/d})^{-1} = \text{IEF (d/year)} \times (\text{risk/pCi})$  (see Table 5 in the main text). The RRFs were used by DRI to compute risks from predicted fluxes.

The RRF was used to calculate annual radionuclide risks for the fluxes predicted to occur at various times. The RRF is the risk resulting from one unit of flux (i.e., 1 pCi/d). For example, an RRF for tritium was calculated in tables in the text of the report as  $1.16 \times 10^{-25} (\text{pCi/d})^{-1}$ . This risk factor was used by DRI to calculate the expected risk level from the flux of tritium computed by the groundwater transport model. The equation for this calculation is  $\text{risk} = \text{flux (pCi/d)} \times \text{RRF (pCi/d)}^{-1}$  (Table 5 in the main text).

The RRFs were used to calculate cancer risks from each radionuclide using the flux predictions. The risks from all radionuclides were summed to compute the risk from each year's predicted radionuclide fluxes. These values were then used to calculate the cumulative lifetime risk. The reported risks are the sum of risks calculated for each time step of the groundwater model over a period of 70 years. For example, the lifetime risk reported to occur one year after the first detonation is the risk expected for a 70-year exposure beginning at year one. A similar sum was computed for each time step. Results from all three sites were added to calculate the risk from possible exposure to radionuclides to marine life from the three plumes.

### ***A.13.1 Discussion of Uncertainties***

There is no uncertainty in the mathematical process of calculating cancer risks, which involves multiplying numbers calculated according to the foregoing risk assessment model elements. The risk is calculated by multiplying the radionuclide flux at each time step of the groundwater model by the RRF. RRF is calculated by multiplying the IEF by the CMRC.



## ***A.14.0 Relationships of Site Closure Activities***

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There are three main activities in the overall site closure plan: (1) the groundwater model, (2) the screening risk assessment, and (3) the closure plan itself. All of these activities are governed by DOE. The material in this report advances the approach, methods, and data by which the screening risk assessment was performed and reported.