HH/R-14

RTI INTERNATIONAL **Memo to File**

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Reviewer: Paul Andrews **Date:**

Subject: Documentation of radiation dose modeling

Section No.	Subsection No.	Figure/Table Number	Other	Page Number
4.12				

Background:

The potential offsite radiological impacts to key receptors from routine effluent releases were assessed through calculations estimating the annual committed effective dose equivalent (CEDE). The term "dose equivalent" refers to a 50-year committed dose equivalent. The sum of the effluent related doses and direct dose equivalents provides an estimate of the total effective dose equivalent (TEDE) associated with the combined Wilmington site operations (proposed GLE facility + existing FMO facility). The calculated annual dose equivalents were then compared to regulatory (EPA and NRC) radiation exposure standards as a way of illustrating the magnitude of potential impacts. The key receptors (critical populations) evaluated were the resident nearest to the proposed GLE facility and the maximum exposed individual (MEI, located just south of the southern site boundary near the FMO, as shown in Figure 4.12-2). The MEI is a hypothetical person living at the point of highest projected total uranium concentrations near the site boundary. The dose impact was evaluated for inhalation and cloud plume immersion and direct dose from ground plane deposition resulting from gaseous emissions from both emitters at the Site. The dietary contribution of radiological dose from consuming locally produced meats, vegetables, and dairy was not considered based on the very low concentrations measured in nearby vegetation resulting from FMO operations. Similarly, no radiological contamination of drinking water is anticipated or considered in the analysis. The analysis included dose equivalent assessments for four age groups (adults, teens, children, and infants) for these pathways.

Doses were calculated using GENII (version 2.06), which was developed for the U.S. EPA to provide a set of programs for calculating radiation dose and risk from radionuclides released to the environment. GENII implements dosimetry models recommended by the International Commission on Radiological Protection (ICRP) in Publications 26, 30, 48, and 56 through 72, and the related risk factors published in Federal Guidance Report 13. The option to calculate doses and/or risks using ICRP-30 and -48 factors (Federal Guidance Reports 11 and 12) was selected as these methods have

been approved by DOE. The ICRP dosimetry and risk models are considered to be state-of-the-art by the international radiation protection community and have been adopted by most national and international organizations as their standard dosimetry methodology (Napier, 2007). The NRC's XOQDOQ air dispersion model was used to estimate the offsite airborne unitized concentrations and relative deposition rate of uranium isotopes averaged for one year of emissions.

Box A
Results:

Dose equivalents for the MEI and the nearest resident were calculated by pathway for the total body in adults, teens, children, and infants, and are presented in Tables 4.12-1 and 4.12-2, respectively. The CEDE for the adult MEI from the combined FMO and GLE emissions was calculated to be 8.1E-6 mSv (8.1E-4 mrem) per year. For the adult full-time resident nearest to the proposed GLE facility, the CEDE from the combined FMO and GLE emissions was calculated to be 5.8E-6 mSv (5.8E-4 mrem) per year. These doses are well below the EPA 10 mrem per year standard and the NRC TEDE 100 mrem per year limit.

Box B
Calculations/Logic: How was the answer to the results (Box A) obtained?

See below.

RTI INTERNATIONAL Memo to File

Box C
References:

Napier, Bruce A. 2007. *GENII Version 2 Users' Guide.* Prepared for U.S. Environmental Protection Agency under Contract DE-AC05-76RLO 1830.

USEPA. 1993. *Federal Guidance Report No. 12. External Exposure to Radionuclides in Air, Water, and Soil.* EPA-402-R-93-081.

USEPA. 1999. *Federal Guidance Report No. 13. Cancer Risk Coefficients for Environmental Exposure to Radionuclides.* EPA-402-R-99-001.

NRCS (National Resource Conservation Service). 2006b. *U.S. General Soil Map (STATSGO).* Online information. U.S. Department of Agriculture, National Resource Conservation Service, National Cartography and Geospatial Center, Fort Worth, TX. Available at http://www.ncgc.nrcs.usda.gov/products/datasets/statsgo/index.html (accessed September 6, 2007).

Rationale for model selection:

GENII (version 2.06) was developed for the U.S. EPA to provide a set of programs for calculating radiation dose and risk from radionuclides released to the environment. GENII implements dosimetry models recommended by the ICRP in Publications 26, 30, 48, and 56 through 72, and the related risk factors published in Federal Guidance Report 13. The ICRP dosimetry and risk models are considered to be state-of-the-art by the international radiation protection community and have been adopted by most national and international organizations as their standard dosimetry methodology (Napier, 2007). The GENII model is fully documented, reviewed, and tested. GENII (version 1.0) was released by DOE in 1988. EPA released version 2.0 in 2002, incorporating improved transport models, exposure options, dose and risk estimation, and user interfaces. It is being actively maintained and updated by an EPA contractor. Other models were also investigated; we did not use COMPLY because it is a screening model (not intended to represent actual doses to real people) and older and its data inputs and outputs are poorly documented.

MEI documentation:

Modules =

- Constituent (linked to all 4 other modules)
  - Selected GENII Radionuclide Database. This module allows the user to select constituents of concern. The database also provides some key chemical properties for other modules.
  - Selected U234, U235, U236, U238, Th231, and Th234. Note that user is forced to include thorium automatically when selecting uranium constituents (because thorium is the resulting decay product); we did not populate or utilize any input, intermediate, or output data for thorium (no emission rates provided by client, assumed to be 0).
  - Used all default chemical/physical properties.
- User_defined (linked to Exposure_Pathways)
  - Selected FRAMES ATO Air Module. This module was used because we had calculated the concentrations, deposition rates, and/or external dose in air (using XOQDOQ and stack emission rates, not discussed here). The constituent concentrations, deposition rates, and external doses all at user provided points in time, are entered directly through the interface. This module does not compute the ingrowth of progeny because the user is assumed to know everything about the source, including progeny emission. Therefore, this module assumes that the progeny emissions are input along with the parent emissions.
  - All constituents described as flux type = particle 1 and output type = air concentration with dry deposition.
  - The constituent description used was fine particles with a radius of 1 μm. This was chosen, rather than a gas, because it allowed the model to calculate effects of soil inhalation and external ground exposure. This small radius was chosen because it was assumed that the isotopes depositing would likely be in the form of UO_2F_2, which is a particulate that forms from gaseous UF_6.
  - Data are same for year = 0 and 1. Data were generated using XOQDOQ and stack emission rates; data entry by P. Andrews and confirmed by S. Wolf.

P1 dry Bq/m^2/yr	AC P1 Ci/m^3		
0.010271337	6.24253E-19	U234	MEI
0.000401463	2.44E-20	U235	MEI
4.52028E-06	2.75E-22	U236	MEI
0.001459012	8.87E-20	U238	MEI

- Exposure_Pathways (linked to Receptor_Intakes)
  - Selected *GENII V.2 Chronic Exposure Module.* The GENII chronic exposure module may be used to estimate concentrations in exposure media for groundwater, surface water, and atmospheric transport

pathways. The analysis accepts concentration data for waterborne pathways, and annual average atmospheric transport values. Deposition to soil from air or irrigation may be considered prior to the start of the exposure period. The results of the analysis are written in annual increments for the duration of exposure defined by the user. Exposure pathways include domestic water use (including irrigation of home gardens), agricultural product consumption, aquatic food consumption, recreational surface water activities, and soil contamination pathways. Losses by leaching, harvest removal, and radioactive decay from the surface soil are evaluated.

- The **main control screen** ("Controls") for the GENII chronic exposure user interface allows the user to make general selections on exposure pathways to include, and to define some basic parameters for the exposure analysis. The general selections allow inclusion (control box checked) or exclusion of general classes of exposure pathways.
  Animal product ingestion (UNCHECKED)
  Terrestrial food ingestion (UNCHECKED)
  Aquatic food ingestion (UNCHECKED)
  Recreational surface water exposures (UNCHECKED)

Duration of exposure is the time period over which the individual is exposed. It is measured from the time given for the start of exposure. VALUE ENTERED = 1.0 yr

End of release period is the elapsed time measured from time zero to the end of the release. Exposures may be evaluated beyond this time period for exposure to residual activity. VALUE ENTERED = 1.0 yr

Time from start to exposure is the time from zero to the beginning of the intake analysis. The duration of exposure begins at the end of the "time from start to exposure." VALUE ENTERED = 0.0 yr

Air deposition time prior to exposure is used when atmospheric releases are being evaluated. This time period is measured backwards from the "time from start to exposure" and must be less than or equal to that time parameter. ~~VALUE~~ ENTERED = 0 yr

Absolute humidity is used in the special tritium models only. VALUE ENTERED = DEFAULT = 0.008 kg/m^3 (not utilized)

Fraction of plant roots in surface soil is used in the food crop and animal feed analyses and represents the fraction of plant roots that are in the contaminated

soil layer. The uptake by plants is assumed to be proportional to this fraction. VALUE ENTERED = DEFAULT = 1.0 fraction (not utilized)

Average daily rain rate is used to estimate the interception fraction from rain when wet deposition rates are provided in the atmospheric transport output file (ATO), and the user has selected the option to allow the code to calculate the wet deposition interception fraction. Note that the rainfall rates are not transferred with the ATO file, and a consistent value must be re-entered here. The value should reflect the rate "when it is raining", not the annual average. VALUE ENTERED = 3.1 mm/hr (more realistic average rainfall rate (when raining) for Wilmington of 3.1 mm/hr was substituted for the default value of 1 mm/d), based on examination of National Weather Service observations from Wilmington Airport.

Soil - Leaching Screen

The *type of leach rate constant* option allows selection of the method for specifying the soil loss rate constant for the leaching model. The rate constant may be defined in three ways: use of values in the GENII transport factor data file, calculation of rate constants from user supplied parameters, or input of rate constants (for each radionuclide). The method is selected from the pull-down list. When use of the GENII transport factor data file is selected, no additional input is needed for this screen. VALUE ENTERED = GENII default leach rates

Soil - Resuspension Screen

The *type of model to run* selects the model to use to evaluate air concentration from calculated soil concentrations. Four options are available: none (no resuspended contamination), use mass loading model, use Anspaugh model, and user input of resuspension factor. VALUE ENTERED = Use Anspaugh model (b/c this model assumes that material deposited will always be fresh)

The *mass loading factor for resuspension model* parameter is GREYED OUT.

The *depth of topsoil available for resuspension* parameter is entered when the Anspaugh model is selected. This parameter represents the thickness of soil in which the deposited activity has been mixed. VALUE ENTERED = 1 cm (default)

The *resuspension factor* is GREYED OUT.

Soil - Surface Soil Screen

The *surface soil areal density* is used to convert concentrations expressed per unit area to concentrations expressed per unit soil mass. VALUE ENTERED = 35496.0 mg/cm^2 (NRCS , 2006b)

The *surface soil layer used for density* is the depth of soil used in calculation of the soil areal density. VALUE ENTERED = 13.7 in (Both the MEI and nearest resident locations are in the Johnston-Dorovan-Meggett soil regime. The maximum depth of the top layer for each type was averaged together.)

The *surface soil density* is the soil mass density used to calculate the soil areal density. VALUE ENTERED = 1.02 g/cm^3 (Both the MEI and nearest resident locations are in the Johnston-Dorovan-Meggett soil regime. The midpoints of the range for bulk density were averaged.)

Agriculture - General Screen

This screen allows the user to describe harvest removal, deposition to plants, and resuspension to plant surfaces, and loss by weathering from plant surfaces. Most concentrations as estimated using the assumption that radionuclides behave as small (micron-range) particles.

The *radionuclide removal due to harvesting* option allows the user to activate ("x" in box) the calculation of radionuclide loss due to harvest removal of each food crop and animal product feed. VALUE ENTERED = not activated.

The *user defined dry deposition retention fraction to plants* option allows the user to select the method for evaluating the dry deposition retention fraction. If this option is activated ("x" in box), then the user is allowed to enter the dry deposition retention fraction to plants (next parameter). If not activated, the code uses the default method based on plant biomass. VALUE ENTERED = not activated.

The *dry deposition retention fraction to plants* is GREYED OUT.

The *user defined wet deposition retention fraction to plants* option allows the user to select the method for evaluating the wet deposition retention fraction. If this option is activiated ("x" in box), then the user is allowed to enter the wet deposition retention fraction to plants (next parameter). If not activated, the code uses the default method based on biomass and rainfall rate. VALUE ENTERED = not activated.

The *wet deposition retention fraction to plants* is GREYED OUT.

The *resuspension factor from soil to plant surfaces* is used to evaluate the air concentration above the plants from resuspension of particulate activity. VALUE ENTERED = 1.00E-09 1/m (default)

The *deposition velocity from soil to plant surfaces* is used to estimate the amount of resuspended activity deposited onto plants. VALUE ENTERED = 0.001 m/s (default)

The *weathering half life from plants* is used to evaluate the weathering loss rate constant for loss of activity between deposition (wet or dry) and harvest. VALUE ENTERED = 14.0 d (default)

Agriculture - Animal Feed Screens - ALL SCREENS GREYED OUT.

Agriculture - Food Crop Screens – ALL SCREENS GREYED OUT.

Agriculture - Intake Delays Screen – GREYED OUT.

Pathways Screen

The selection of exposure pathways is controlled on this screen. Each pathway may be selected for inclusion in the analysis for the current exposure location. The following pathways may be selected.

Animal product (meat, poultry, milk, eggs) ingestion – GREYED OUT.
Food crop (leafy vegetables, root vegetables, fruit, grains) ingestion – GREYED OUT.
Aquatic food (fish, mollusks, crustacea, aquatic plants) ingestion – GREYED OUT.
Drinking water ingestion – GREYED OUT.
Inadvertent shower water ingestion – GREYED OUT.
Inadvertent swimming water ingestion – GREYED OUT.
Inadvertent soil ingestion (based soley on RESIDENTIAL soils) – NOT ACTIVATED
Inhalation of outdoor air contaminated from atmospheric transport. For complete exposure coverage, also select Indoor air. – ACTIVATED
Inhalation of indoor air, which includes contributions from outdoor air plus contaminants released from domestic water during showering and other uses. For complete coverage, also include outdoor air. – ACTIVATED
Inhalation of suspended soil from prior air or irrigation deposition – ACTIVATED
External exposure from waterborne activity while swimming – GREYED OUT.
External exposure from waterborne activity while boating – GREYED OUT.
External exposure from sediment activity while on shoreline – GREYED OUT.
External exposure from soil activity (based solely on RESIDENTIAL soils) –

ACTIVATED
External exposure to airborne activity from atmospheric transport – ACTIVATED

The external exposure to air may be evaluated using the finite plume model or the semi-infinite plume model. When the finite plume model is checked, the external dose values are read directly from the atmospheric transport file (ATO) and no calculations are performed for this pathway in the GENII chronic exposure module. Otherwise, a semi-infinite plume is assumed and the dose is to be based on the air concentration. *Finite plume model* – NOT ACTIVATED.

- Receptor_Intakes (linked to Health_Impacts)
  - Selected *GENII V.2 Receptor Intake Module*. The GENII V.2 intake module may be used to estimate annual, time-integrated intakes from exposure to contaminated soil, groundwater, surface water, and atmospheric transport pathways. Up to 6 age groups may be specified.
  - 4 age groups selected. Age group 1 (infant) defined as 0 – 1 yr. Age group 2 (child) defined as 2 – 12 yr. Age group 3 (teen) defined as 13 – 19 yr. Age group 4 (adult) defined as 20 – 70 yr. Data for each pathway selected is the same for each age group.
  - Pathway = *external exposure to air.*
    - *Daily plume immersion exposure time* = 24.0 hr
    - *Yearly plume immersion exposure time* = 365.0 day
  - Pathway = *external ground exposure.*
    - *Indoor shielding factor* = 0.7 unitless (FGR12, p.189)
    - *Outdoor shielding factor* = 1.0 unitless
    - *Daily external ground exposure time* = 24.0 hr
    - *Yearly external ground exposure time* = 182.5 day
    - *Fraction of time spent indoors* = 0.7 fraction (FGR12, p.190)
    - *Fraction of time spent outdoors* = 0.3 fraction
  - Pathway = *external exposure while swimming*
    - ALL DEFAULTS USED
  - Pathway = *external exposure while boating*
    - ALL DEFAULTS USED
  - Pathway = *external exposure to shoreline*
    - ALL DEFAULTS USED
  - Pathway = *food crop ingestion*
    - ALL DEFAULTS USED
  - Pathway = *animal product ingestion*
    - ALL DEFAULTS USED
  - Pathway = *aquatic food ingestion*
    - ALL DEFAULTS USED
  - Pathway = *drinking water ingestion*
    - ALL DEFAULTS USED

- Pathway = *water ingestion while swimming*
  - ALL DEFAULTS USED
- Pathway = *water ingestion while showering*
  - ALL DEFAULTS USED
- Pathway = *inadvertent soil ingestion*
  - ALL DEFAULTS USED
- Pathway = *air inhalation (data from Federal Guidance Report No. 13, Table 3.1; assume 1 year old = infant, 10 year old = child, 15 year old = teen, 20+ = adult)*
  - *Air inhalation rate* = 5.2 m^3/day (infant)
  - *Air inhalation rate* = 15.3 m^3/day (child)
  - *Air inhalation rate* = 20.1 m^3/day (teen)
  - *Air inhalation rate* = 22.2 m^3/day (adult)
  - *Air inhalation period* = 365.0 day/year
  - *Fraction of a day outdoor inhalation occurs* = 0.3 fraction
- Pathway = *resuspended soil inhalation (data from Federal Guidance Report No. 13, Table 3.1)*
  - *Resuspended soil inhalation rate* = 5.2 m^3/day (infant)
  - *Resuspended soil inhalation rate* = 15.3 m^3/day (child)
  - *Resuspended soil inhalation rate* = 20.1 m^3/day (teen)
  - *Resuspended soil inhalation rate* = 22.2 m^3/day (adult)
  - *Resuspended soil inhalation period* = 365.0 day/year
  - *Fraction of a day inhalation of resuspension* = 1.0 fraction
- Pathway = *indoor air inhalation (data from Federal Guidance Report No. 13, Table 3.1)*
  - *Indoor inhalation rate* = 5.2 m^3/day (infant)
  - *Indoor inhalation rate* = 15.3 m^3/day (child)
  - *Indoor inhalation rate* = 20.1 m^3/day (teen)
  - *Indoor inhalation rate* = 22.2 m^3/day (adult)
  - *Indoor inhalation period* = 365.0 day/year
  - *Fraction of a day indoor inhalation occurs* = 0.7 fraction

- Health_Impacts
  - Selected *GENII V.2 Health Impact Module*. The GENII V.2 health impact module calculates health impacts from intake or exposure to radionuclides. Radionuclide health impacts may be reported as radiation dose, cancer incidence, or fatal cancer incidence. Radiation risk calculations can be based on ICRP dosimetry and health effects conversion factors (user defined), or on EPA/HEAST radionuclide slope factors. The module includes consideration of domestic water use, farm product consumption, aquatic food consumption, surface water recreational activities, soil contact exposure, and air exposures.

- **Method Selections** Screen. Three options are available. Check the appropriate box.
- **Calculate dose and risk using ICRP-30/48 factors (Federal Guidance Reports 11 and 12)**: This option allows calculation of doses and/or risks using DOE-approved methods. The radiation dosimetry is based on ICRP Publication 30 (as updated), as provided in Federal Guidance Reports 11 and 12 or DOE compilations DOE/EH-0070 and DOE/EH-0071. THIS OPTION ACTIVATED.
- **Calculate dose and/or risk using ICRP-60/72 and EPA risk factors**: This option allows calculation of doses and/or risks using EPA-approved methods. The radiation dosimetry is based on ICRP Publications 60 and 72, as provided in the supporting documents for Federal Guidance Reports 12 and 13. THIS OPTION NOT SELECTED
- **Calculate risk using EPA slope factors:** This option allows calculation of radiation risk using EPA slope factors. Slope factors were originally provided in the EPA Health Effects Assessment Summary Tables (HEAST); HEAST is no longer published by EPA and the slope factors are now taken from the Federal Guidance Report No. 13 values for adults. THIS OPTION NOT SELECTED
- Selection of **Calculate dose and risk using ICRP-30/48 factors** activates a "Method Parameters" tab. Options for calculating radiation dose, fatal cancers, or cancer incidence are available. Select one or more. ONLY "CALCULATE RADIATION EFFECTIVE DOSE EQUIVALENT COMMITMENT (CEDE)" SELECTED.
- Two additional parameters related to the estimation of external dose rates are also required. These should be set with the values used in preceding modules.
- *Thickness of contaminated soil/sediment layer – SOILT* = 0.3 m
- *Density of contaminated soil/sediment layer – SLDN* = 1020 kg/m^3

Nearest resident documentation:

All same as MEI except concentration data =

- User_defined (linked to Exposure_Pathways)
  - Data are same for year = 0 and 1. Data were generated using XOQDOQ and stack data; data entry by P. Andrews and confirmed by S. Wolf.

P1 dry Bq/m^2/yr	AC P1 Ci/m^3		
0.004659041	4.29E-19	U234	Nearest resident
0.000182072	1.92E-20	U235	Nearest resident
2.05921E-06	2.18E-22	U236	Nearest resident
0.000661771	6.99E-20	U238	Nearest resident

Nearest fenceline (to GLE stack) documentation:

All same as MEI except concentration data =

- User_defined (linked to Exposure_Pathways)
  - Data are same for year = 0 and 1. Data were generated using XOQDOQ and stack data; data entry by P. Andrews and confirmed by S. Wolf.

P1 dry Bq/m^2/yr	AC P1 Ci/m^3		
0.003163315	4.13E-19	U234	Nearest fenceline
0.000123635	1.61E-20	U235	Nearest fenceline
1.39203E-06	1.82E-22	U236	Nearest fenceline
0.000448985	5.87E-20	U238	Nearest fenceline